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SOLAR CONSTANT (SOLCON) EXPERIMENT: GROUND SUPPORT EQUIPMENT (GSE) SOFTWARE DEVELOPMENT

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Hampton, Virginia

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Abstract

The Solar Constant (SOLCON) Experiment, the objective of which is to determine the solar constant value and its variability, is scheduled for launch as part of the Space Shuttle's Atmospheric Laboratory for Application and Science (ATLAS) spacelab mission. The Ground Support Equipment (GSE) software was developed to monitor and analyze the SOLCON Telemetry data during flight and to test the instrument on the ground. This paper presents the design and development of the GSE software. The SOLCON instrument was tested during Davos International Solar Intercomparison, 1989. The SOLCON data collected during the tests were analyzed to study the behavior of the instrument.

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LIST OF ACRONYMS

Acronym	Description
ATLAS	Atmospheric Laboratory for Applications and Science
DAMP	Data Analysis and Monitoring Program
DCP88	Dedicated Communication Processor
DEP	Dedicated Experiment Protocol
DPU	Digital Processing Unit
ECIO	Experiment Computer Input Output
ERBE	Earth Radiation Budget Experiment
ESA	European Space Agency
ESTEC	European Space Technical Center
GSE	Ground Support Equipment
ITE	Instrument Test Equipment
IRMB	The Royal Meteorological Institute of Belgium
KSFC	Kennedy Space Flight Center
LaRC	Langley Research Center
MSFC	Marshall Space Flight Center
SEID	Spacelab Experiment Interface Device
SOLCON	Solar Constant
SOVA	Solar Constant and Variability

1.0 INTRODUCTION

The Royal Meteorological Institute of Belgium (IRMB) has developed a series of spacecraft experiments designed to define the magnitude of the solar constant (total solar irradiance which is normalized to the mean Earth/Sun distance). The basic pyrheliometer is an active cavity, electrical-substitution radiometer[1] which was flown on the Space Shuttle Spacelab I Mission during December 1983. A Solar Constant and Variability (SOVA) version of the IRMB radiometer will be launched on a European Space Agency (ESA) platform before 1994. The Solar Constant (SOLCON) version of the radiometer is scheduled for launch as part of the Space Shuttle Atmospheric Laboratory for Applications and Science (ATLAS) Mission in March 1992. The prime objective of the SOLCON experiment is to determine the solar constant value, its variability, and its spectral irradiance[2]. The Principal Investigator for the SOLCON experiment is Dr. Dominique Crommelynck of the Royal Meteorological Institute of Belgium (IRMB).

SOLCON is one of eleven experiments which comprise the ATLAS Mission. ATLAS is a series of Space Shuttle Spacelab Missions which investigate how the Earth's atmosphere and climate are affected by the Sun, by the products of industrial complexes, and by agricultural activities. These experiments will be flown on the shuttle every year or two throughout the Sun's eleven-year activity cycle. Three of the eleven instruments in ATLAS1 Mission are solar experiments. They are SOLCON, Active Cavity Radiometer (ACR), and Solar Spectrum (SOLSPEC). SOLCON and ACR experiments measure ultraviolet through infrared solar radiation, and each experiment will determine a value for the solar constant which will be compared.

The SOLCON instrument consists of two parts: SOLCON I and SOLCON II. SOLCON I is a dual cavity absolute radiometer[3]. It uses the cavities to absorb the radiation and the electrically calibrated thermal heat flux transducers to measure the radiative power. Both cavities have shutters which alternately open and close. The radiometer is operated with 98.7-second shutter closed and open periods. The instrument has sixteen different modes of operation. In the normally used active mode, one of the cavities is always closed and the other is alternately opened and closed. The closed cavity is heated with a constant power. The difference of the two thermopiles sensing the temperature is used to control the heater of the alternately opened and closed cavity such that the heat fluxes in the cavities remain the same. The main analog signals, such as current and voltage across the heater element, are measured simultaneously by dedicated channels of the data acquisition system. SOLCON I has a set of two sunphotometers with custom filters at 546 and 480 nm. The sunphotometers are used to measure the spectral irradiance to monitor spectral distribution and solar spectral oscillations. It also has a coarse sensor to provide its own pointing information with respect to the Sun. The sensor of the Sun pointing monitor is a four quadrant sector silicium cell. When the four quadrants are equally irradiated, the instrument is aligned directly with the Sun. SOLCON II is the Digital Processing Unit (DPU), which contains software that provides control, timing, and interface between the sensor (SOLCON I) and the spacecraft.

The software developed for the functioning of the instrument is the Digital Processing Unit (DPU) software and the Ground Support Equipment (GSE) software. The DPU software controls the sensor, performs data acquisition from the sensor, and manages the spacecraft interface protocol. GSE software is used to store, display and analyze the SOLCON Telemetry data and is also used for testing the instrument on the ground. This report describes the GSE software developed for SOLCON.

Following is the sequence of events to fulfill the SOLCON experiment of the ATLAS mission.

1. The development of software for the SOLCON instrument.

2. The intercomparisons and field tests for the SOLCON instrument at Davos, Switzerland, during October 1989.

3. The off-line testing and delivery of the instrument at Kennedy Space Flight Center (KSFC) in April 1990; to integrate with the payload for ATLAS mission.

4. The functional tests of the instrument at KSFC, scheduled for January 1991.

5. The all systems tests of the instruments for the ATLAS mission, at KSFC during March/April 1991.

6. The simulations for the ATLAS mission at Marshall Space Flight Center (MSFC) in August 1991.

7. The flight of the instrument aboard the Space Shuttle in March 1992.

8. Analysis of the flight data from the instrument collected during the ATLAS mission.

2.0 DEVELOPMENT OF SOFTWARE

The software written for the SOLCON GSE consists of two programs: ITE software and the DAMP. The original ITE version was obtained from the ESA's SOVA Project. LaRC was responsible for converting the SOVA ITE software to the SOLCON ITE. The DAMP program provided more monitoring and data analysis capabilities and eventually, replaced ITE software as the primary SOLCON GSE program.

2.1 ITE SOFTWARE

The ITE program primarily functioned as testing software for the instrument (SOLCON I) and the Digital Processing Unit (DPU or SOLCON II). The ITE tests each DPU command sequence to ensure proper execution. For example, the "RAD05" command places SOLCON I into a specific configuration (i.e. both shutters are closed, reference side is left, etc.) known as radiometric state five. The ITE issues the "RAD05" command to the DPU and waits for the telemetry data. Upon the arrival of telemetry data, the ITE subprogram verifies that the instrument has entered the radiometric state five. The ITE subprogram checks the instrument status to verify the proper radiometric state five configurations. When the ITE has completed the command validation, the ITE prints out a report of all errors found during the test.

The ITE program contains multiple window displays. These displays provide the Test Conductor with information on the telemetry received from the DPU, on the status of communications between DPU and GSE, on the errors generated during the test, and on the commands sent to the DPU. Along with the screen displays, the ITE prints information to the output printer. All the error messages, that are displayed on the screen, are also directed to the printer for a hard copy record. The telemetry display window can be copied to the printer either continuously or in snapshot mode. Printer options are available to dump the exact bit-by-bit contents of the telemetry data packet. This information is useful for examining the data packets in minute detail. The telemetry data can also be directed to the printer in engineering units. The data packets are saved in a data file on the hard disk drive shortly after arriving from the DPU. The ITE software is an excellent software package for testing both the instrument and the DPU.

2.1.1 DESIGN OF THE ITE

The ITE is divided into four distinct parts or levels: DCP88 modules, kernel modules, monitor modules, and test modules. The different levels are designed to build on one another. The DCP88 level handles the low level communications. The next level, kernel, provides primitives for all input/output operations. The monitor level uses the primitive I/O functions to display and/or print elementary telemetry parameters. The final level, test, uses all previous levels to analyze command sequences and display telemetry data. The following paragraphs describe the four levels in more detail.

The DCP88 modules primarily function as the protocol interface code. The DCP88 modules maintain the GSE portion of the protocol between the ITE computer system and the DPU, and they also provide a print buffer for the ITE program. The DCP88 software runs on the Dedicated Communication Processor computer card(DCP88). The DCP88 card is a computer card with four serial(RS232) ports, one parallel port, an Intel 8088 processor, and 256 kilobytes of on board memory.

The DCP88 has the same computer power as the IBM PC (without disk drives). The card functions as a separate computer, allowing the host (IBM PC or compatible) computer to operate without the time dependent task of servicing a protocol request or printer chores.

The DCP88 modules, in executable form, are downloaded to the DCP88 card through shared memory. The host computer activates the DCP88 card, which then begins handling the GSE protocol task and printing chores. The DCP88 code continuously monitors the serial (RS232) lines. Upon receiving new input from a serial line, the DCP88 code reacts in accordance to the Dedicated Experiment Protocol(DEP) requirements. For example, when a telemetry packet is received, the packet must be checked for transmitting errors, decoded, and stored in the telemetry buffer. The telemetry packet waits in the buffer until the host computer is ready to process. The protocol code must respond with an acknowledgement to the waiting DPU in order to complete the protocol sequence. The DCP88 software provides print buffer support for the host computer. The DCP88 code monitors the printer's status, and fills the printer's buffer whenever required. The DCP88 code monitors the host computer for new requests. The host computer can request the DCP88 to perform any of the following: send commands to the DPU, send data to the printer, or ask for the next available telemetry packet. The host communicates with the DCP88 card through the shared memory located on the DCP88 card. The DCP88 code operates in a continuous loop. The loop repeatedly checks the RS232 lines and the host computer, for new data to process. The DCP88 card functions in parallel with the host computer, therefore, allowing the overall design of the ITE to be less complicated.

The DCP88 modules interface with the kernel modules, which is the next higher level. The kernel modules are low-level support modules of the ITE's host computer program. They support the following functions: window management, spooler management, instrument command processing, and raw data file management. The two levels above the kernel (monitor and test) use the kernel subroutines to display information in the various windows on the screen, to print data to different pages on the printer, to manipulate command strings and deliver commands to the DCP88 card, and to store raw telemetry data in a disk file. The kernel modules provide a set of common routines which can be called by the upper level modules.

The monitor level acts as a filter to the telemetry data. The monitor modules are responsible for requesting new telemetry packets from the telemetry buffer on the DCP88 card. After acquiring a new data packet, the monitor module process the packet according to the packet type. The packet is either unpacked and displayed in the monitor window or passed to the next level (test) for more processing. A binary dump option is available to direct binary output of the packets to the printer. The monitor module filters out all science packets which are not required by the current test subprogram.

The test modules constitute the highest level of the ITE software. The Test Conductor activates a test module to validate a command sequence. The test module controls and validates the entire test procedure; which includes sending and verifying commands, analyzing science packet contents, displaying science packet data, printing science data, and indicating any abnormalities in the test data. There is a test module for each command sequence. The test modules also include procedure for unpacking science frames, validating science frames, and issuing commands.

In summary, the ITE program has four levels: DCP88, kernel, monitor, and test. The DCP88 is the lowest level and performs the time critical functions (i.e. printing and protocol management). The kernel provides low level interface to the DCP88 card, printer, display screen, and disk drive control. The third level is the monitor level. At this level, the report/exception data packets are unpacked and displayed. The unwanted science packets are filtered out before the packets are transmitted to the test level. The test level is the highest level of the ITE software. The science packets are unpacked and displayed. The instrument commands are issued, and high level error checking are performed at the test level. The ITE design is a highly complex piece of software, which required a considerable effort to understand.

2.1.2 CHANGES TO THE ITE SOFTWARE

The ITE SOVA software was converted into the ITE SOLCON software. The ITE code is approximately 15,000 lines of code and consists of approximately 75 modules. The SOVA ITE documentation lacked structure charts and data flow diagrams which are used in determining how the modules interface with one another. The ITE code flows very nicely once the structure of the program is understood. Conversion of the ITE SOVA software to ITE SOLCON software required a detailed understanding of the ITE design. The lack of a structure chart and the large number of modules made the conversion very difficult to perform in the short time frame allowed.

Converting the SOVA ITE to SOLCON ITE required major changes to the protocol and to Telemetry data format. The protocol change only affected the DCP88 card's software (localized) which simplified the modification. The SOVA protocol modules were replaced by the SOLCON protocol modules. The SOVA software used two serial lines for operating the DPU/instrument: one for commanding and the other for telemetry data transfer. The SOLCON version reduced the number of communication lines to one, by sending commands and telemetry over the same serial line. The protocol was changed to a subset of the dedicated experiment protocol, which is also used by the DPU to communicate to the Space Shuttle. Approximately fifty percent of the DCP88 code was rewritten to accommodate the new protocol.

The SOVA telemetry format was changed to the SOLCON telemetry (TM) format. This modification was more complicated than the protocol change because the protocol change was localized. The telemetry format effects most of the ITE program at all the different levels. The monitor modules were modified to correctly filter the new TM packets. The test modules had to be altered to unpack the new TM packets. A TM software code alteration in one area effects the entire program, making the modification extremely complicated when considering the size of the program. Since the new telemetry format contains all the housekeeping data, all references to the SOVA housekeeping packets had to be removed. This includes the displaying, printing, and checking of housekeeping data. The command section was modified to send the actual command string instead of the command number. All of the above changes occurred prior to the first ITE SOLCON testing at European Space Technical Center (ESTEC).

The SOVA ITE software was designed only for testing the DPU/instrument. The SOVA ITE software is inadequate as a data monitor package. Science data is only displayed during a test procedure. At the end of the procedure, the science data is no longer visible. The SOLCON version has a new mode added to allow science data packets to be displayed in engineering units at any time. The print functions, which were previously restricted to test procedures, were added to the monitor level, along with the display capability. Other improvements to the monitor level included decoding report/exception packets and displaying the meaning in the monitor window. These modifications were extremely useful during the Davos International Solar Intercomparision.

The SOLCON ITE software was tested at ESTEC using the breadboard DPU and SOVA I instrument. The SOLCON ITE software executed flawlessly. However, the ITE software had to be modified to compensate for the DPU's inability to receive and transmit characters at the same rate. This was the only change required to make the ITE communicate with the DPU. The data was displayed correctly on the screen, the printer functions worked perfectly, and the data was stored to the disk properly. All the new monitor functions worked as planned.

Dr. Crommmelynck requested two new functions for the Davos Solar intercomparision. A time stamp was added at the end of each data packet stored in the disk file, and a new print function was added to print the science screen on the 11^{th} and 23^{rd} frames. Both of the new requirements were incorporated into the ITE software before the Davos comparison. The ITE SOLCON and SOVA software lacked a way to replay the data file that was acquired during testing or monitoring operations. A new ITE version was created to replay the data file. The user is given the same printing and screen functions associated with the data acquisition program. The user can control the playback data rate. The replay version was used extensively at the Davos intercomparison.

At Davos, the SOLCON coefficients were added to the ITE software, which required modifying two modules at the test level. Another version of the ITE software was created at Davos to allow the ITE to monitor the telemetry data when the spacelab experiment interface device (SEID) was testing the DPU's interface with the Space Shuttle. This task required major modifications to the protocol module because the ITE does not transmit commands or acknowledge receiving data in the SEID mode. Transforming the original SOVA ITE to the SOLCON ITE involved extensive modifications to the software. The SOLCON ITE software contains many new functions which made the software very valuable as a testing and monitoring tool at the Davos intercomparison.

2.2 DAMP SOFTWARE

2.2.1 BACKGROUND

The idea for the DAMP program originated from working with the Instrument Test Equipment(ITE) program. The ITE was designed only to test the DPU(Digital Processing Unit)/instrument. The DAMP program was to go beyond testing, by introducing real-time solar constant calculations, multi-screen displays, real-time data analysis, real-time plotting, and replay capabilities. The design work began after receiving Dr. Crommelynck's opinions on the functions that the DAMP program should perform. The design goals were divided into two phases.

2.2.2 DESIGN OF THE DAMP

2.2.2.1 Phase 1

Phase 1 was the development of a baseline system to be used as the kernel for future specialized data analysis developments. This baseline system included multi-screen displays, replay files as the input source, facilities for managing specialized output modules, and two specialized output modules: "PrintVar" and "DiskVar".

The DAMP program contains four distinct sections: input, calculate, screen display, and output (see Appendix A for the documentation). The DAMP program executes in a continuous loop. Inside the loop, the following functions are performed.

1. Data is received into the program from one of four sources (RS232 DEP protocol, RS232 passive DEP protocol, Experiment Computer Input/Output (ECIO) line, or a replay file). The input source is selected by pressing the appropriate key on the keyboard.

2. When the input data enters the DAMP program, the data is unpacked according to the type of packet. The unpacked data is placed in a record data structure.

3. The record containing the unpacked data is sent to the 'Calculate' module where the data is reduced into engineering units, and the final solar constant values are computed.

4. The data, in the form of engineering units, are sent to the 'Display' module where they are placed onto the display screen. The user has the option of three different screen displays which can be changed by pressing the appropriate key on the keyboard.

5. The data, in the form of engineering units, are also sent to the 'Output' module. This module manages the special purpose output modules. There are currently two special purpose output modules: "PrintVar" and "DiskVar." Both allow the user to define which parameters and in what format the data will be printed and/or stored on disk .

6. The final products of the special purpose output modules are hard disk files and/or printer output.

The DAMP program provides a number of command keys which allow the user to select the input source, change the input rate, change display screens, and enable/disable the special purpose output modules. The screen displays worked in both Color Graphics Adapter(CGA) and Enhanced Graphics Adapter(EGA) modes. The user can change between screen displays using the keyboard. The managing module provided multi-configurations for each specialized output module and fed the current processed data into the output modules. Both "PrintVar" and "DiskVar" modules dumped processed data (variables) to output devices. These modules allowed the user to select which variables to dump, where to dump variables (printer or disk file), when to dump variables, and the format to dump variables.

2.2.2.2 Phase 2

After Phase 1 was completed and tested, Phase 2 introduced ECIO software. The ECIO software fed the DAMP program with input data in the same manner as the replay data. The interface between the DAMP program and the ECIO software was simple. The DAMP program called an ECIO procedure, and the ECIO software delivered a unique data packet from the ECIO line.

The specialized output modules were designed to interface with the DAMP program in the same manner as the "PrintVar" and "DiskVar" modules. The specialized output modules provided real-time plotting and real-time data analysis (regression analysis, statistics, etc.). The knowledge gained from reducing the Davos data was used in determining exactly what functions the data analysis module would perform. Phase 2 included making adjustments to the user interface portion of the DAMP program.

DESIGN CONSTRAINTS

1. No "time dependent code"

The "time dependent code" is code which MUST be executed within a finite time. For example, the ECIO interface code MUST be executed within one second; otherwise, data packets will be over written.

The DAMP program must run on a wide variety of IBM PC compatibles. The program must run on very fast (DOLCH 386 25MHz) and very slow (TOSHIBA 1200 XT 8MHz) computers. The design can not guarantee that "time-dependent-code" will be executed on time, due to the wide variation of computer speeds.

2. Minimize the use of computer memory.

The expansibility was built into the DAMP program to provide as much flexibility as possible. The number of specialized output modules, which provides the flexibility, are dependent on the amount of unused memory.

DESIGN CHANGE

The initial design was changed as a result of Dr. Crommelynck's request to incorporate the ITE program functions into the DAMP program. Therefore, two new modes, TEST and SEID, had to be added to the DAMP program.

The TEST mode is used when testing the DPU/instrument on the ground. Commands and telemetry data are sent between the DAMP program and DPU/instrument using the Dedicated Experiment Protocol (DEP) over a RS232 communication line. The SEID mode is used during SEID (Spacelab Experiment Interface Device) testing. The instrument's telemetry data is sent to the DAMP program over a RS232 communication line, using a passive DEP protocol. The DAMP program never transmits to the DPU/instrument (i.e it is passive).

As a result of Dr. Crommelynck's request, the Dedicated Communication Processor(DCP88) computer card was introduced into the DAMP program to provide RS232 support. The design was altered to incorporate the two new modes (TEST, SEID) into the DAMP program.

3.0 INTERCOMPARISON AND FIELD TEST

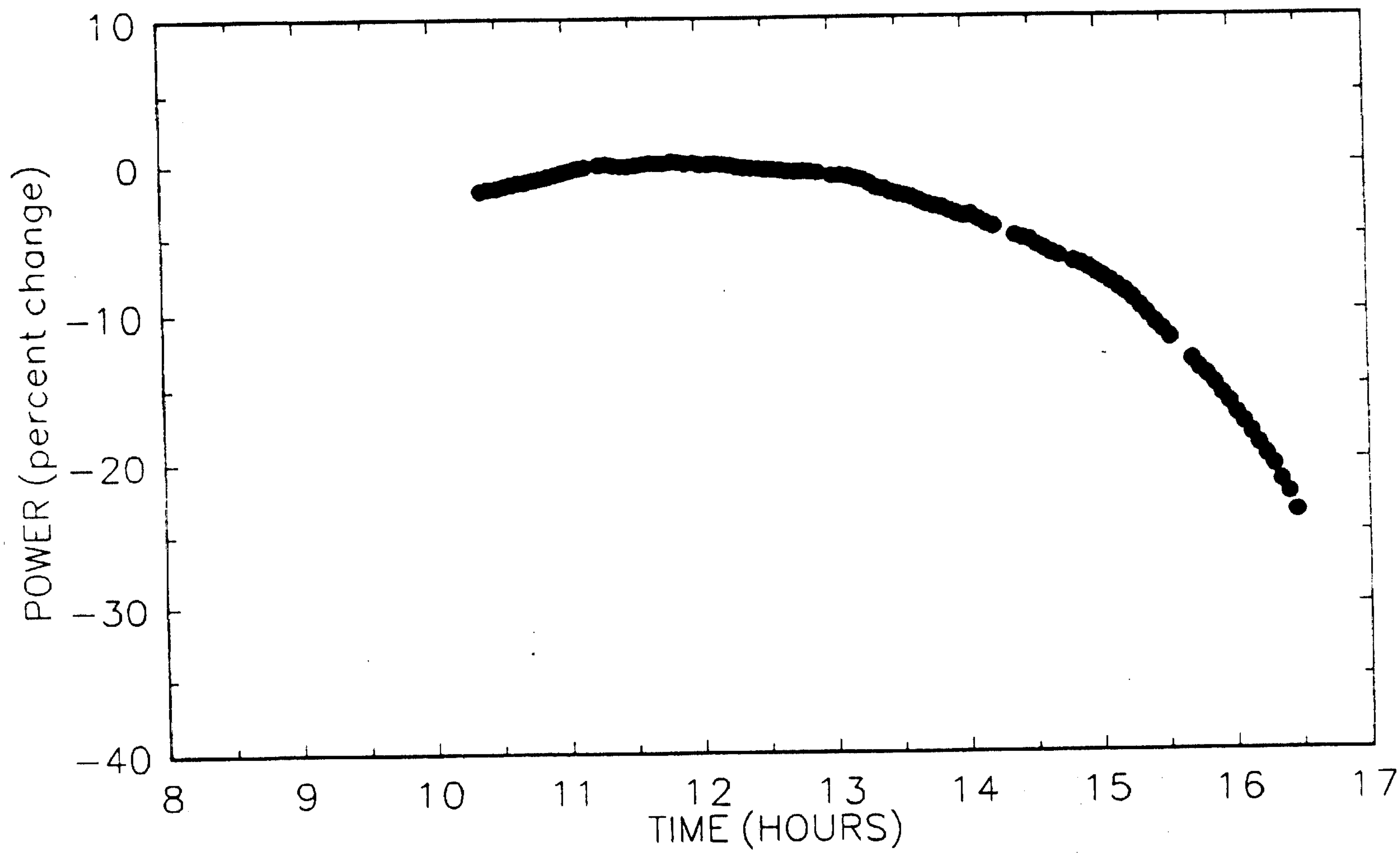
The SOLCON instrument was compared with other radiometers at the Davos International Solar Intercomparison of October 1989. The comparison provides the opportunity for new radiometric instruments to be compared with reference radiometers. The intercomparison yielded an opportunity for the newly completed SOLCON I to be compared with the reference radiometers and to test the GSE software in a real-time data acquisition environment.

The comparison of SOLCON at Davos produced approximately five and one-half days of solar data. The solar data was collected on October 4, 5, 6, 11, 13, and 16, 1989. October 4^{th} and 5^{th} were the two best days; with perfectly clear skies. On October 11, 13, and 16, there were mostly sunny skies with only high, thin clouds. On October 6, the skies were partly sunny in the morning, and in the afternoon a snow storm had moved into the area. Only one-half day's worth of data were retrieved on October 6. The SOLCON heater power measurements are given in Figures 1 through 4.

SOLCON I was mounted on a Sun tracker along with the reference radiometers. The Sun tracker continuously aligns the radiometers with the Sun during the entire day. At the beginning of the day, all the radiometers are synchronized to open their shutters at the same time. The synchronization of the radiometer's shutters minimizes the effects of the variability in the transmittal of the atmosphere. Once the radiometers are synchronized, the GSE must be monitored to ensure the radiometers are functioning properly. The Sun tracker requires adjustments every few hours, causing some data drop out. At the end of the data acquisition period, the GSE turns the radiometers OFF and the tracker assembly is rolled back into the building.

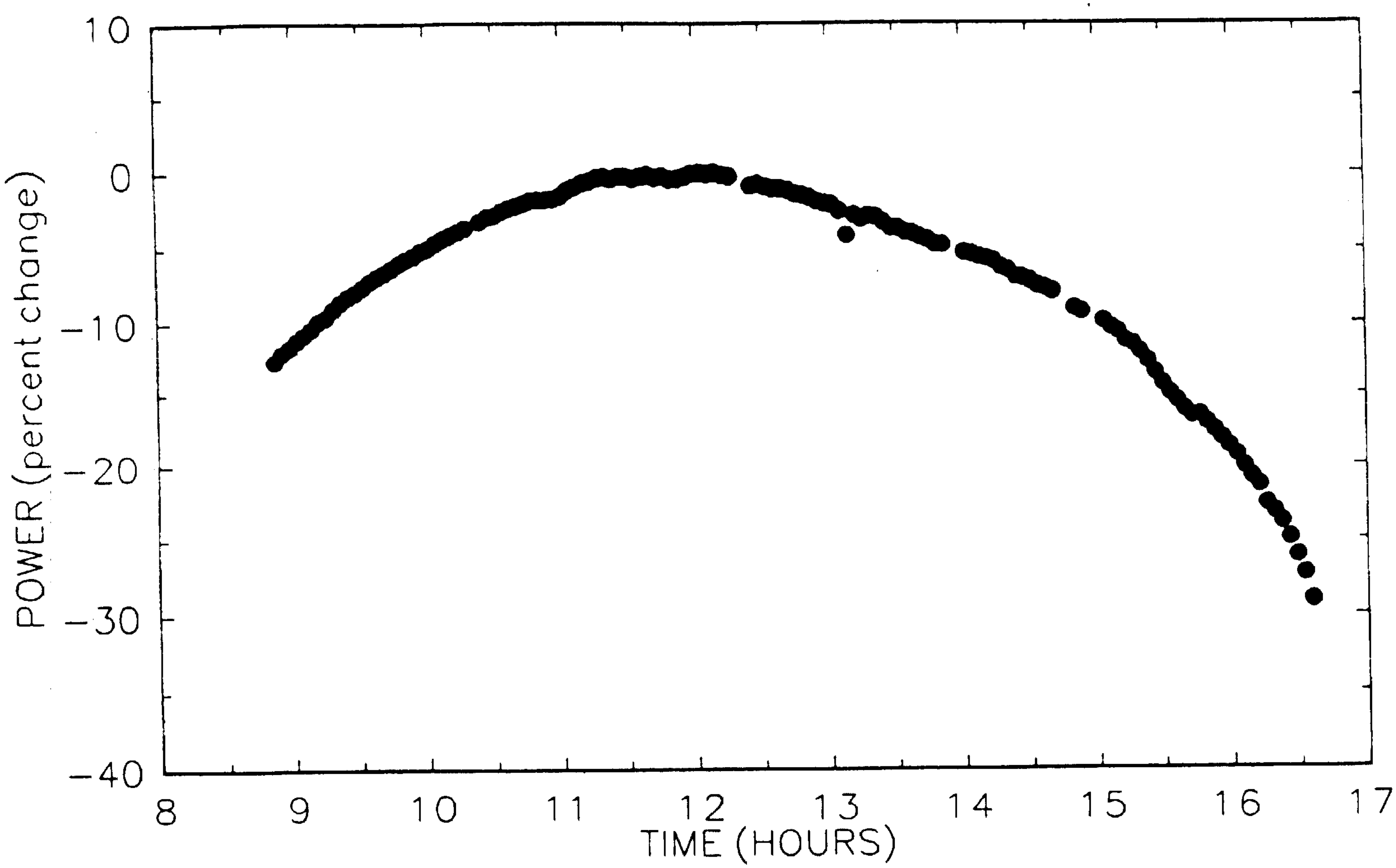
The field testing of the SOLCON GSE software was completed at the Davos intercomparison. The ITE software collected five and one-half days of solar data with no data loss due to software error. There was a 15-minute loss of data due to a Toshiba 1200 hardware problem. The ITE continuously generated hard copy output of the 11^{th} and 23^{rd} science frames. The ITE created hard disk files of all the solar data collected for later data reduction. The replay version of the ITE was tested during the data reducing procedure. The ITE software was turned over to Dr. Crommelynck for use during the SOLCON I and II thermal, vibration, and EMC testing at ESTEC.

Data reduction of the Davos data was a difficult task due to the inconsistent data packet composition. The ITE software, primarily used for testing the instrument and later modified for monitoring data, still lacked the



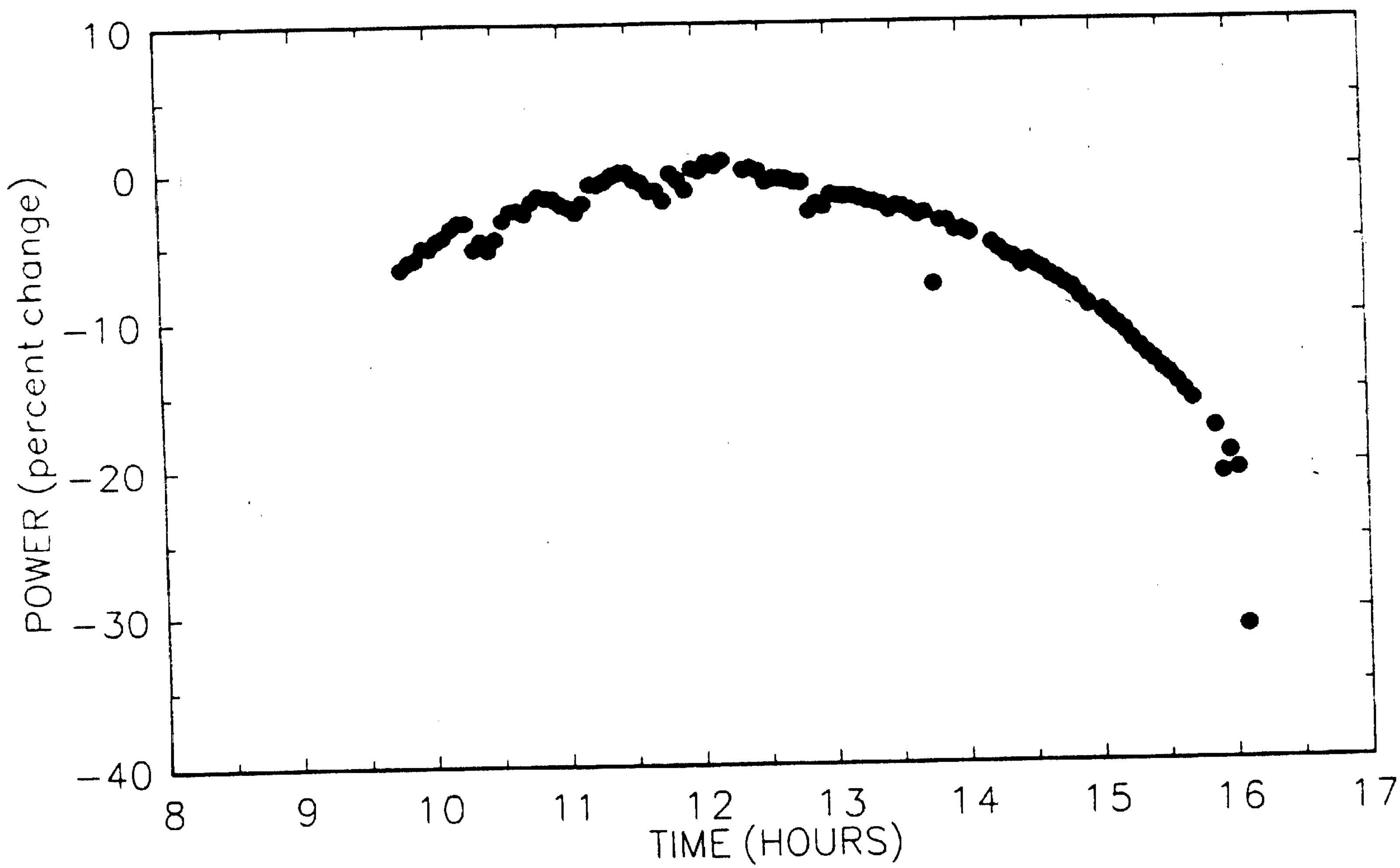
Closed shutter minus open shutter, left cavity.
Percent change relative to 12:00 noon.

FIGURE 1. POWER ABSORBED DURING SOLAR OBSERVATION ON 10/4/89



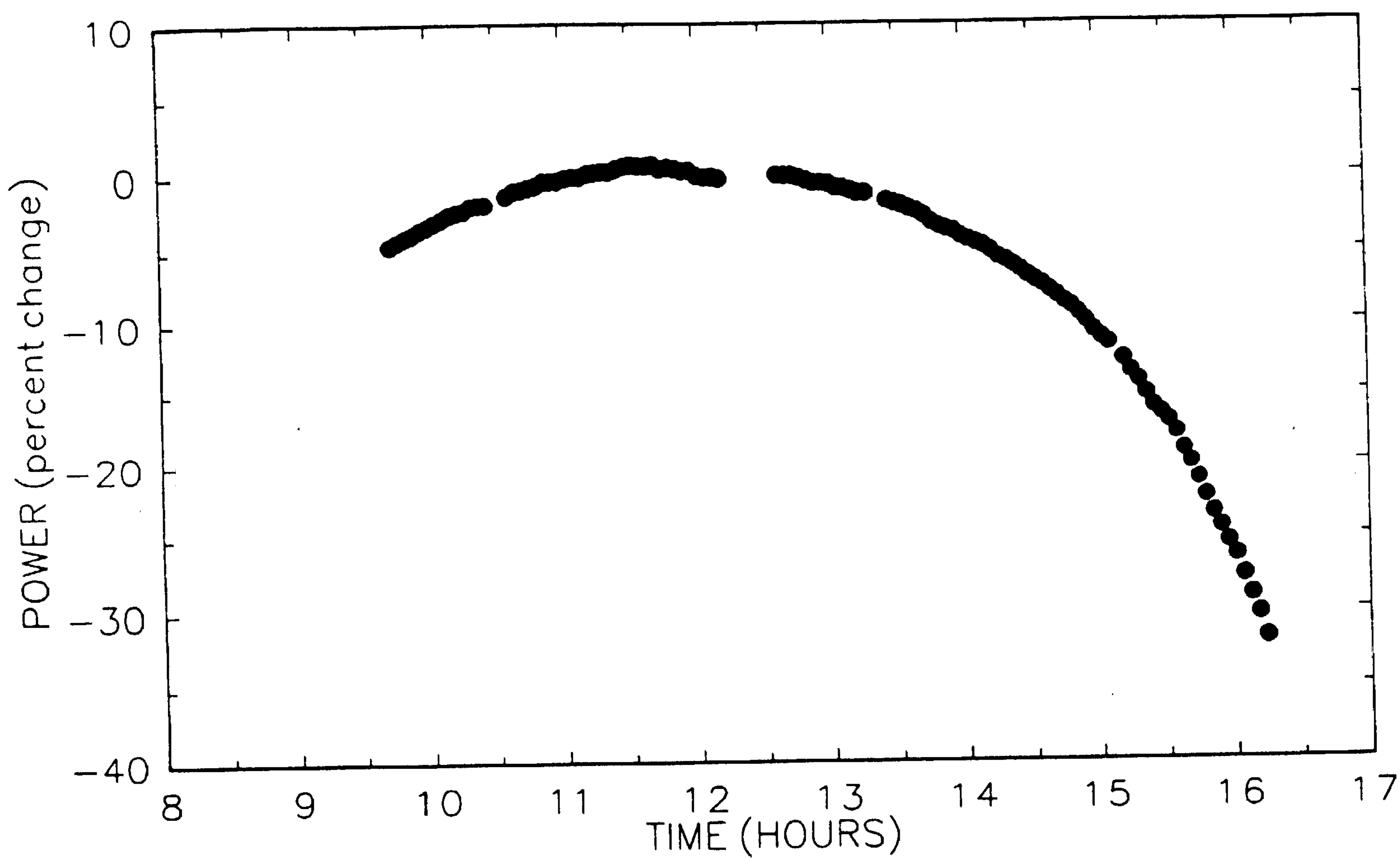
Closed shutter minus open shutter, right cavity.
Percent change relative to 12:00 noon.

FIGURE 2. POWER ABSORBED DURING SOLAR OBSERVATION ON 10/5/89



Closed shutter minus open shutter, right cavity.
Percent change relative to 12:00 noon.

FIGURE 3. POWER ABSORBED DURING SOLAR OBSERVATION ON 10/11/89



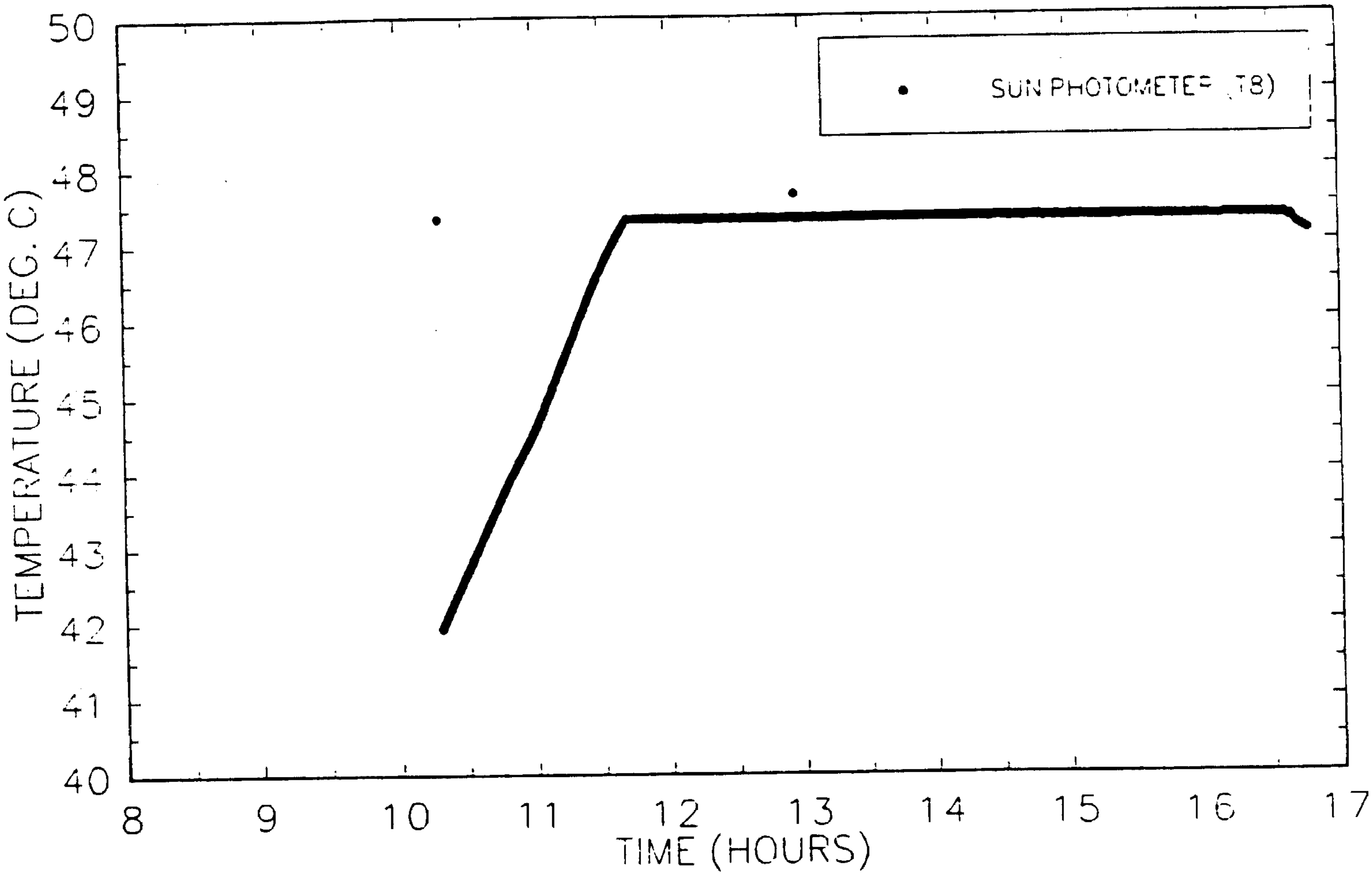
Closed shutter minus open shutter, left cavity.
Percent change relative to 12:00 noon.

FIGURE 4. POWER ABSORBED DURING SOLAR OBSERVATION ON 10/13/89

designed data analysis capabilities. At Davos, the ITE software was modified to generate ASCII data files in a format which could be read in by a spread sheet program for data analysis. Other small data filtering programs were also written to filter out unwanted data, or to interpolate between data points. After the data were brought into the spread sheet, the parameters were plotted against time, and regression analyses were performed on the parameters.

In Figures 5 through 15, the October 4, 1989, instrument parameters are shown plotted against time. The parameters plotted are as follows: all the temperatures, spm1, spm2, resistance, balance, shutter open active side, shutter closed active side, and shutter closed inactive side. The shutter open active side consisted of a series of plots. Each plot in the series shows the first 6-minutes of each hour. These plots provided a close-up look at the signal stabilizing after the shutter moves from the close, to the open position. Figures 16 through 18 represent the results of regression analysis which were performed on several parameters. These include: spm1 vs power measurement during shutter open (active side), spm2 vs power measurement during shutter open (active side), resistance vs base temperature, and power measurement during shutter closed (active side) vs balance.

The results from the plots and regression analysis produced some interesting questions. The temperature plots (Figure 8) showed the left shutter temperature consistently 2-degrees celsius higher than the right shutter. The instrument temperature readings were tested by powering on the instrument at room temperature and monitoring the temperature readings. The right shutter, left aperture, and right aperture temperatures were approximately the same. However, the left shutter temperature read 2-degrees celsius higher than the other three temperature, indicating a temperature calibration problem. In the plots of the spm1 and spm2 (Figure 9), the signal drops indicated one of two situations. The signal drops can be caused by either a cloud passing into the field-of-view or an adjustment to the Sun tracker. The resistance plot (Figure 10) shows a change in resistance when the shutters transfer from open to close. The balance plot (Figure 11) shows a change in the balance when the signal from the active side is in the process of stabilizing. The two regressions (Figure 16), spm1 vs shutter open (active side) and spm2 vs shutter open (active side) were performed



The temperature rises to approximately 47.5 degrees celsius and stabilizes.

FIGURE 5. TEMPERATURE OF THE SUN PHOTOMETERS (T8)

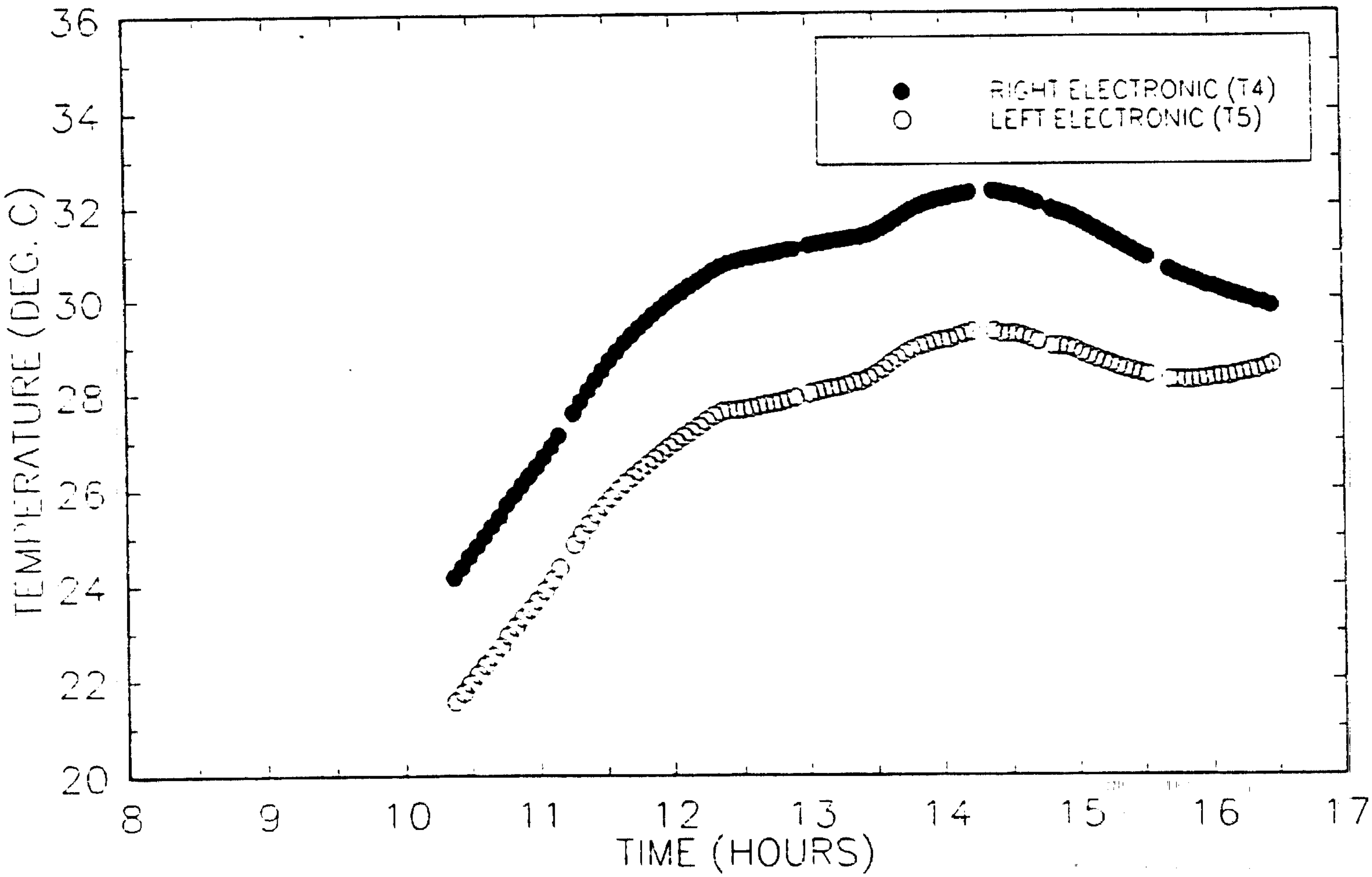


FIGURE 6. TEMPERATURE OF THE ELECTRONICS (T4, T5)

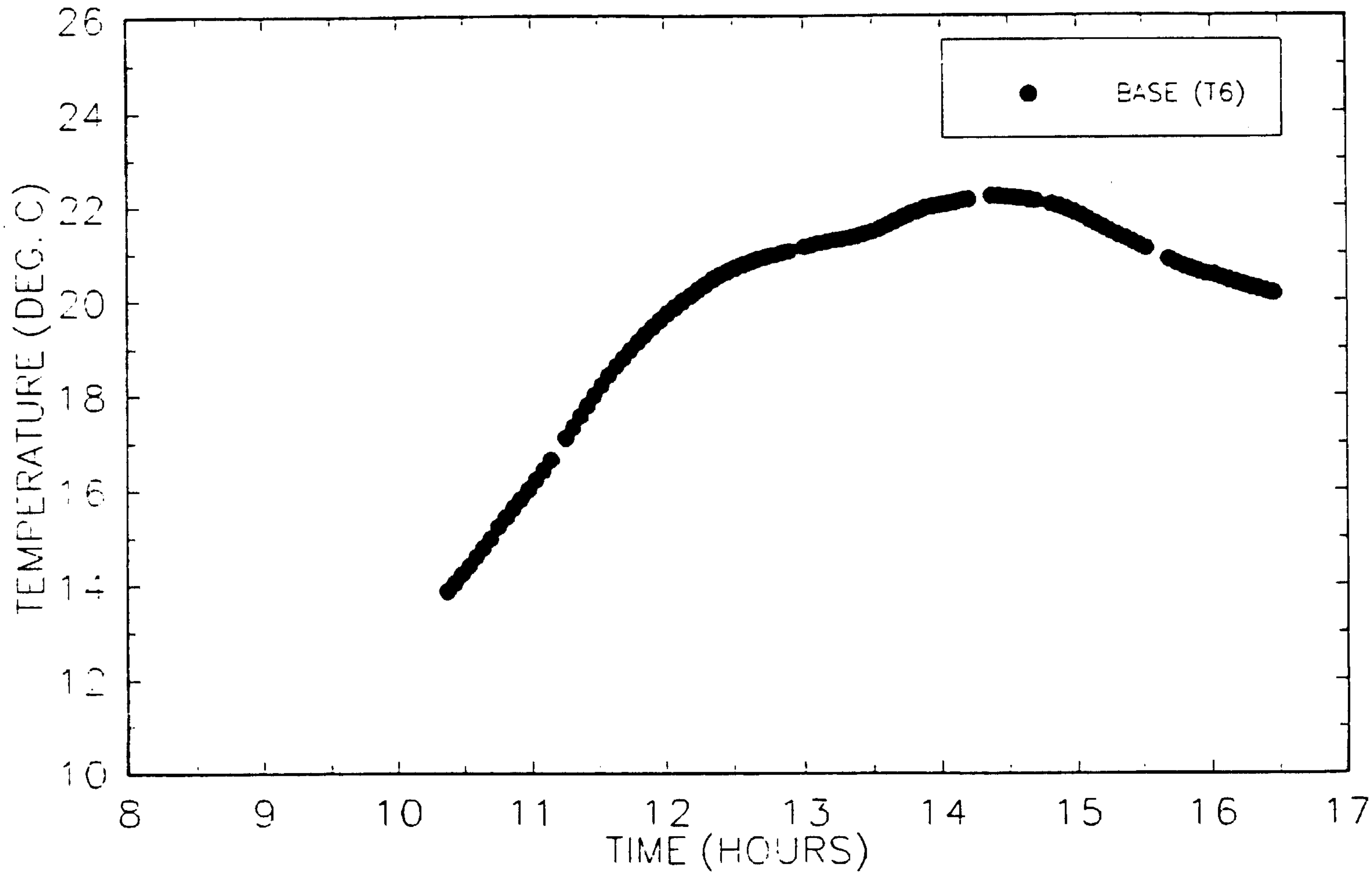


FIGURE 7. BASE TEMPERATURE OF THE SOLCON INSTRUMENT (T6)

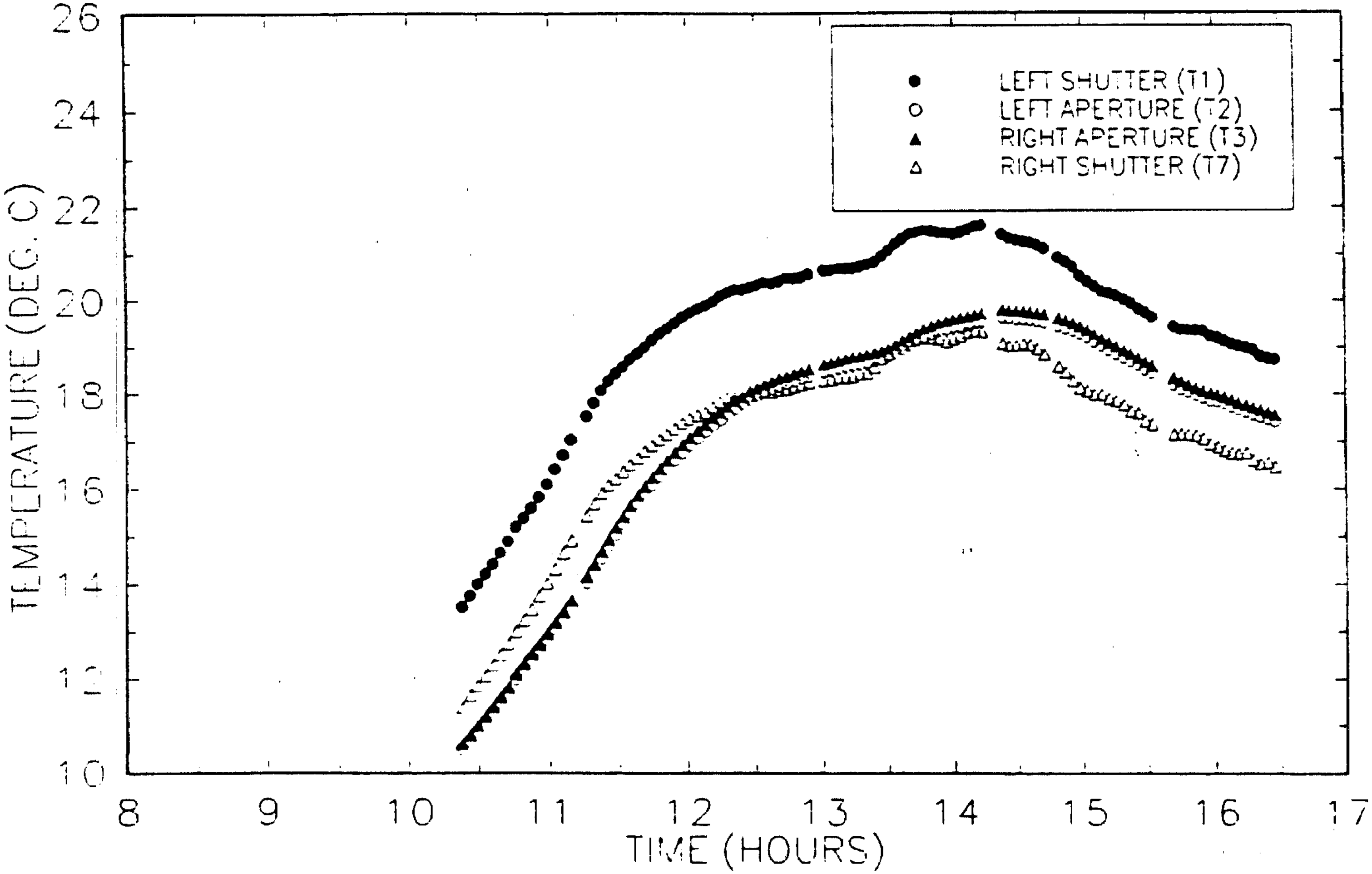
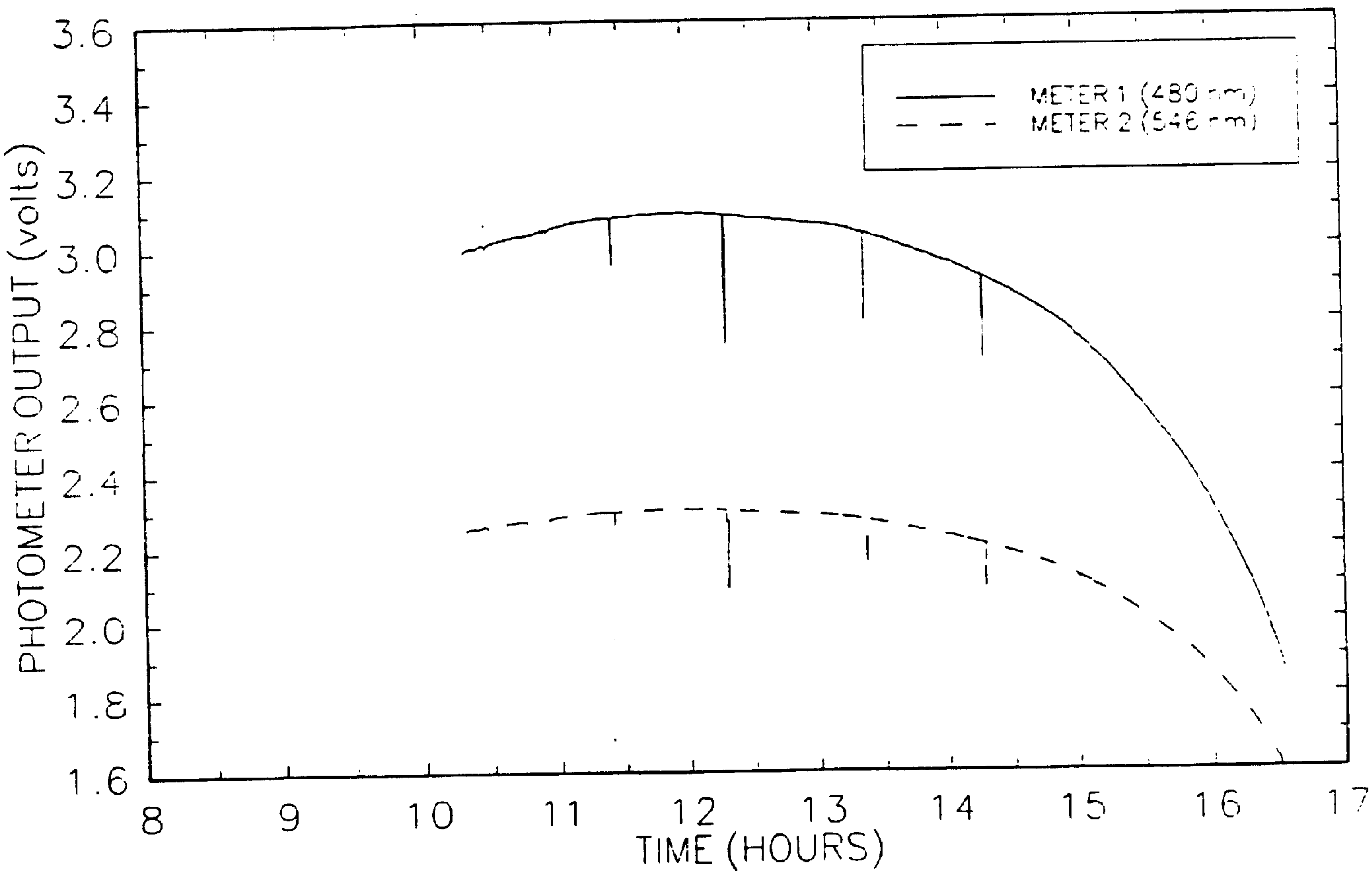
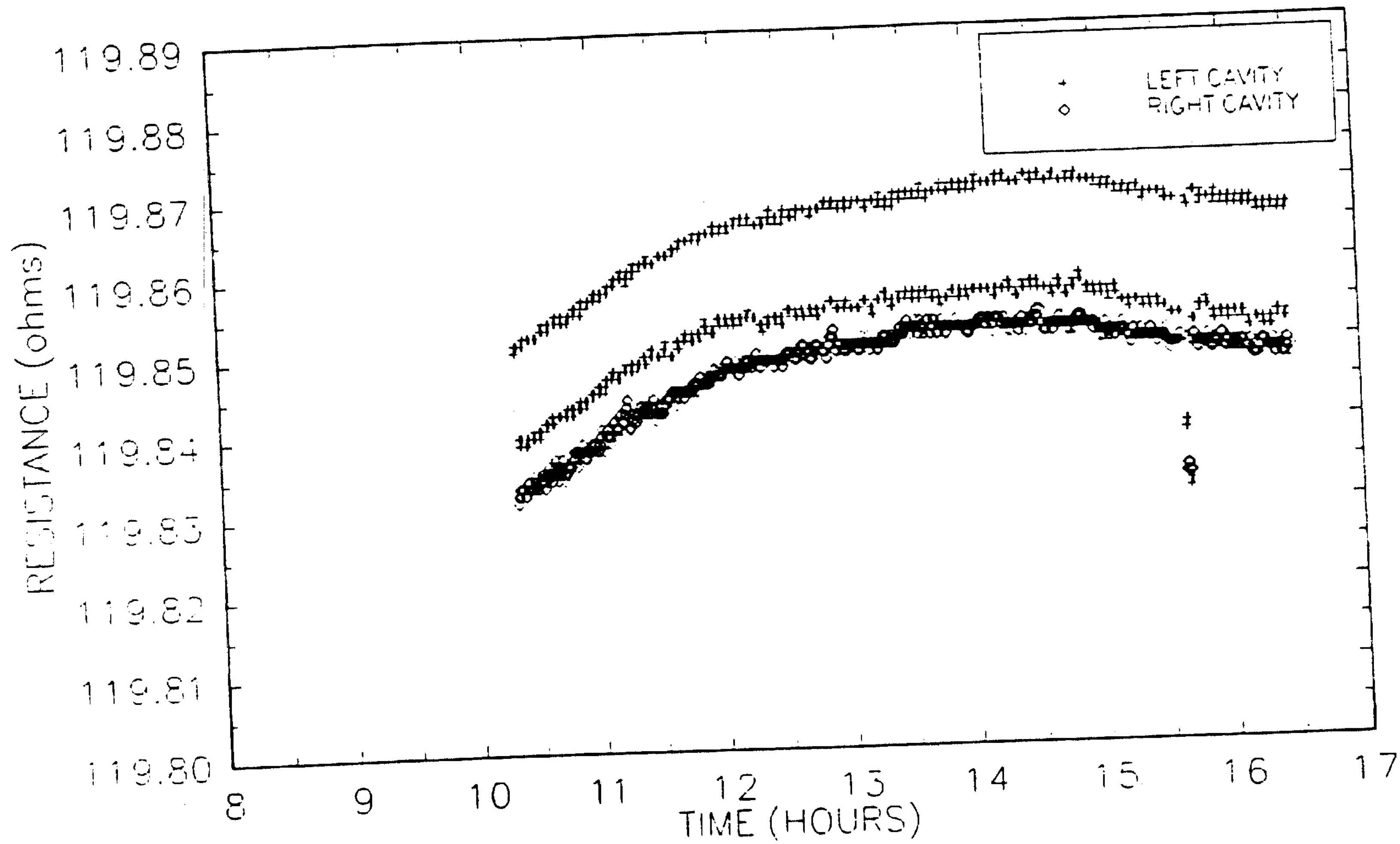


FIGURE 8. TEMPERATURE OF THE SHUTTERS AND APERTURES (T1, T2, T3, T7)



The four spikes in the data were caused by adjustments made to the sun tracker during the observations.

FIGURE 9 . PHOTOMETERS OUTPUT (480 nm AND 546 nm)



The resistance of the active cavity oscillates when the shutter opens and closes.

FIGURE 10. RESISTANCE MEASUREMENTS OF THE SOLCON CAVITIES

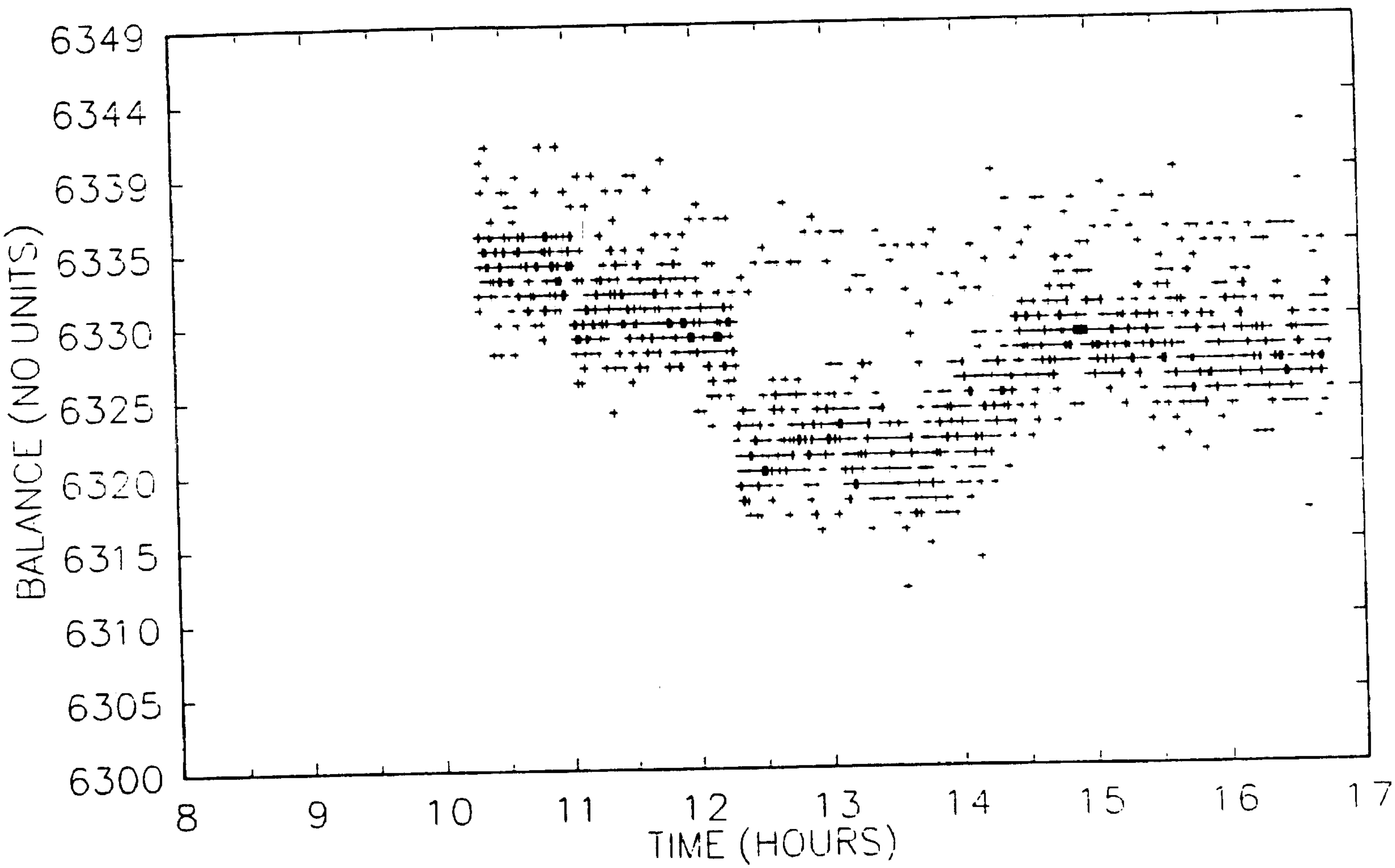


FIGURE 11. BALANCE COUNTS BETWEEN SOLCON'S CAVITIES

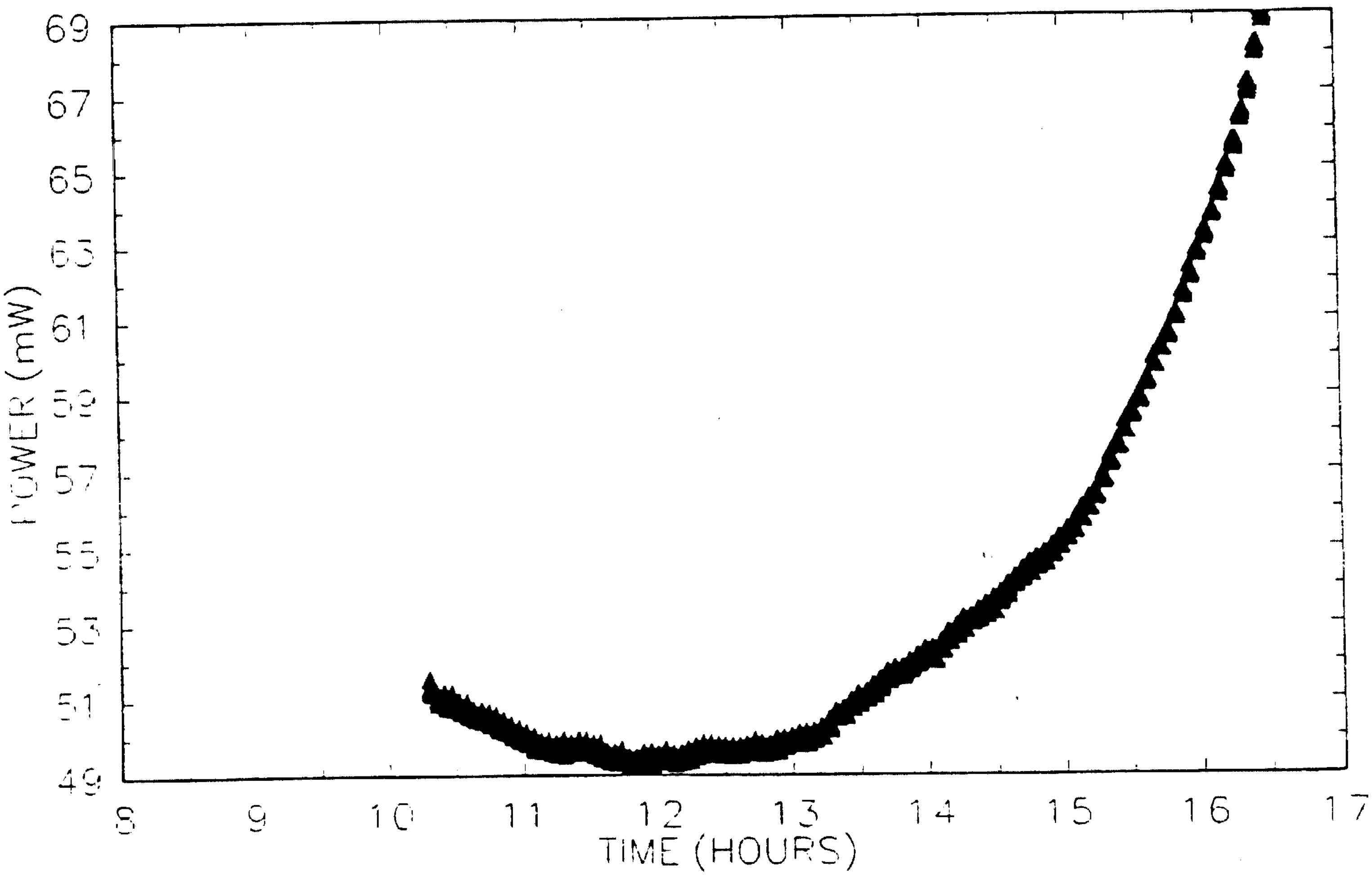
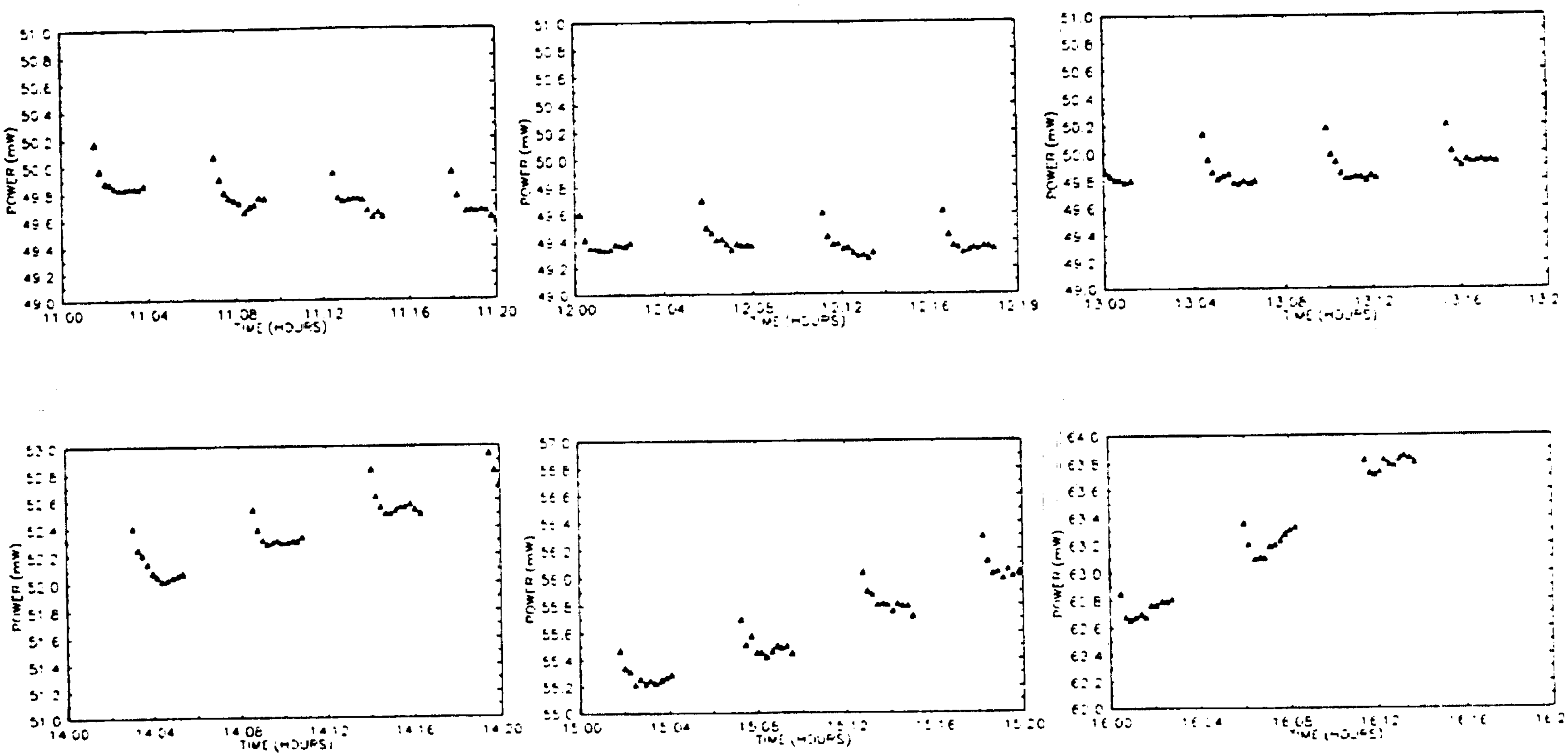
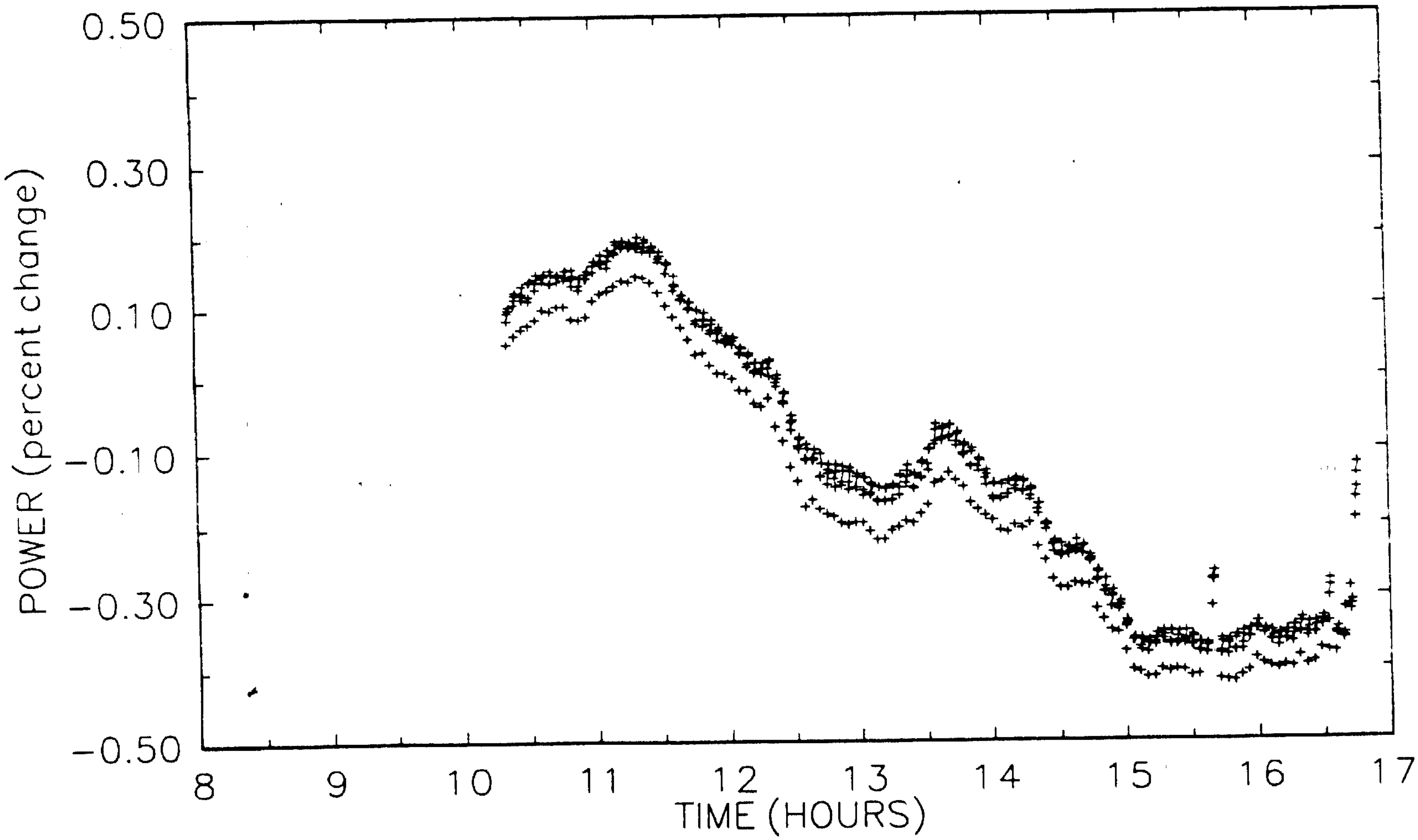


FIGURE 12. POWER MEASUREMENTS DURING SHUTTER OPEN (ACTIVE SIDE)



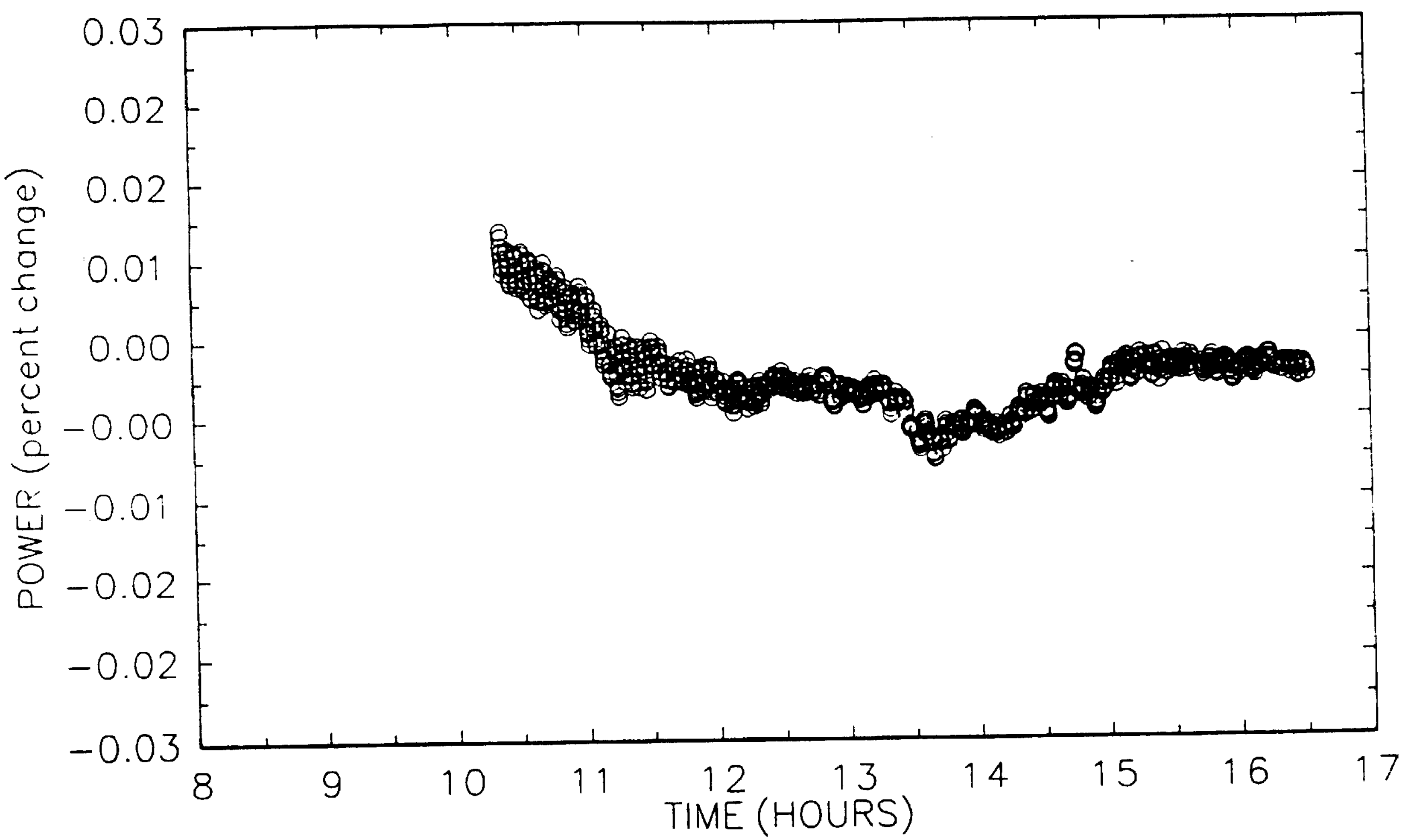
The power readings are expanded to view the transition between closed shutter and open shutter.

FIGURE 13. EXPANDED VIEW OF POWER MEASUREMENTS



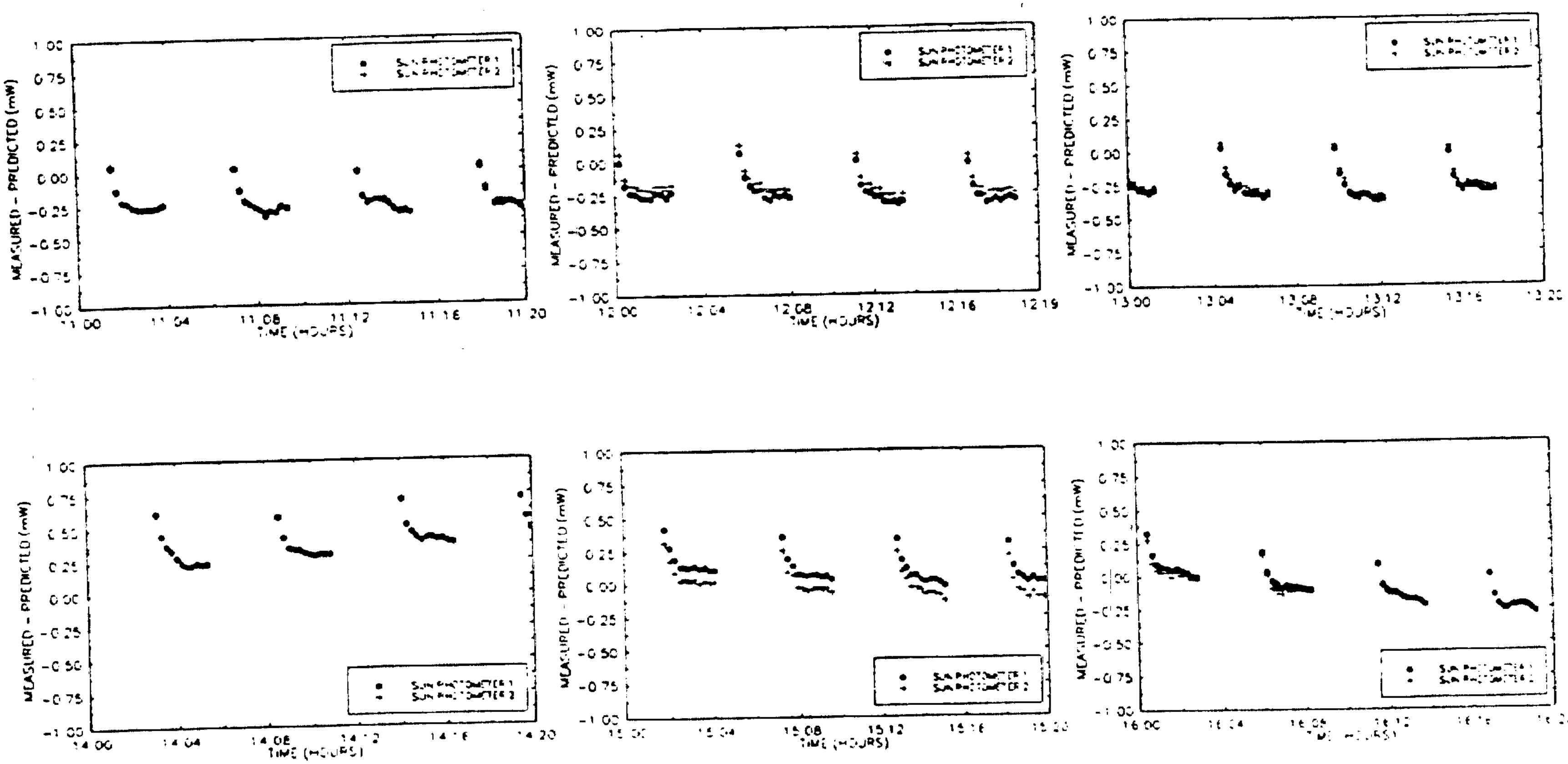
The erratic change in the power readings over the observation period is believed to be caused by operating the instrument in air (power in percent change relative to 12:00 noon).

FIGURE 14. POWER MEASUREMENTS DURING SHUTTER CLOSED (ACTIVE SIDE)



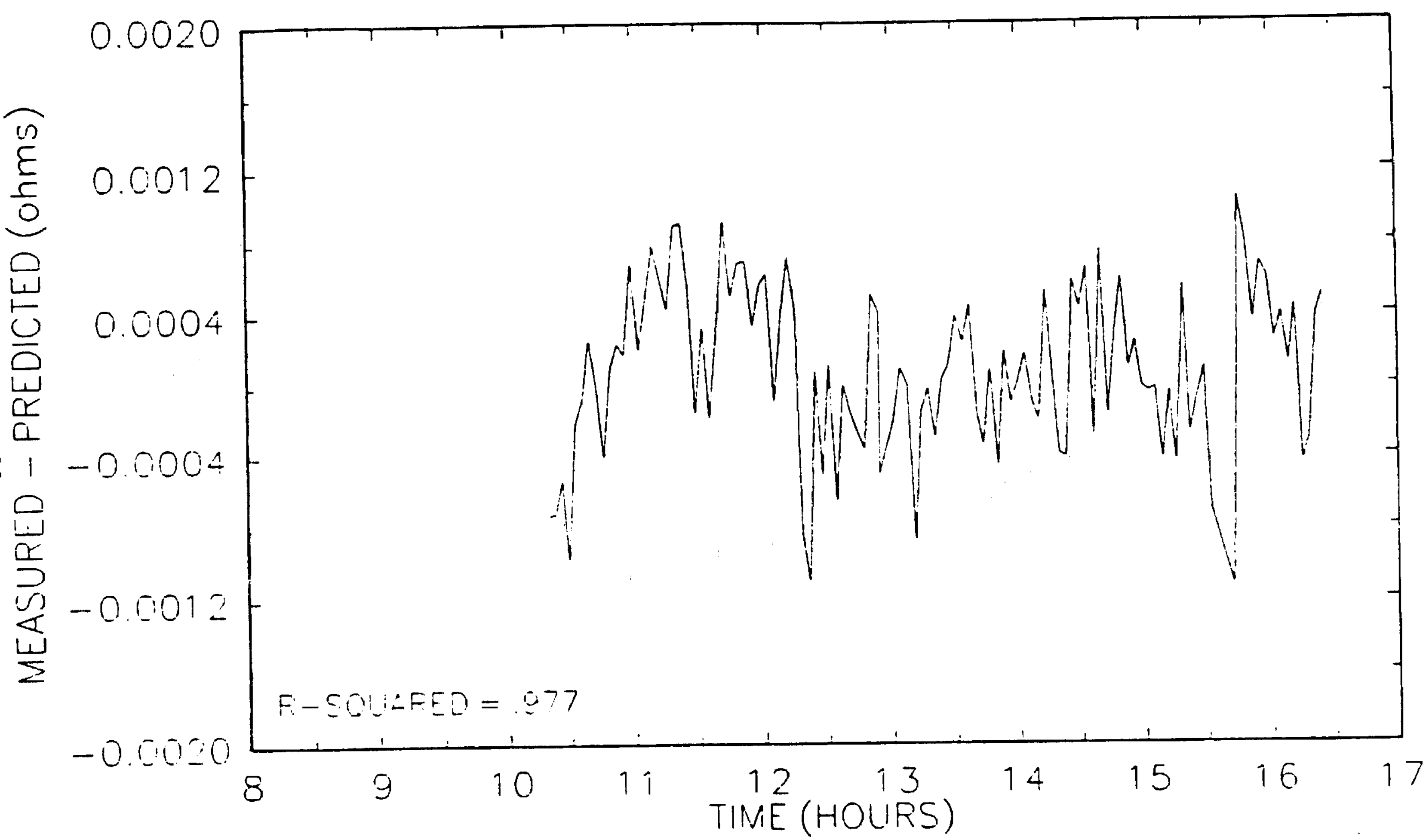
Power in percent change relative to 12:00 noon

FIGURE 15. POWER MEASUREMENTS DURING SHUTTER CLOSED (INACTIVE SIDE)



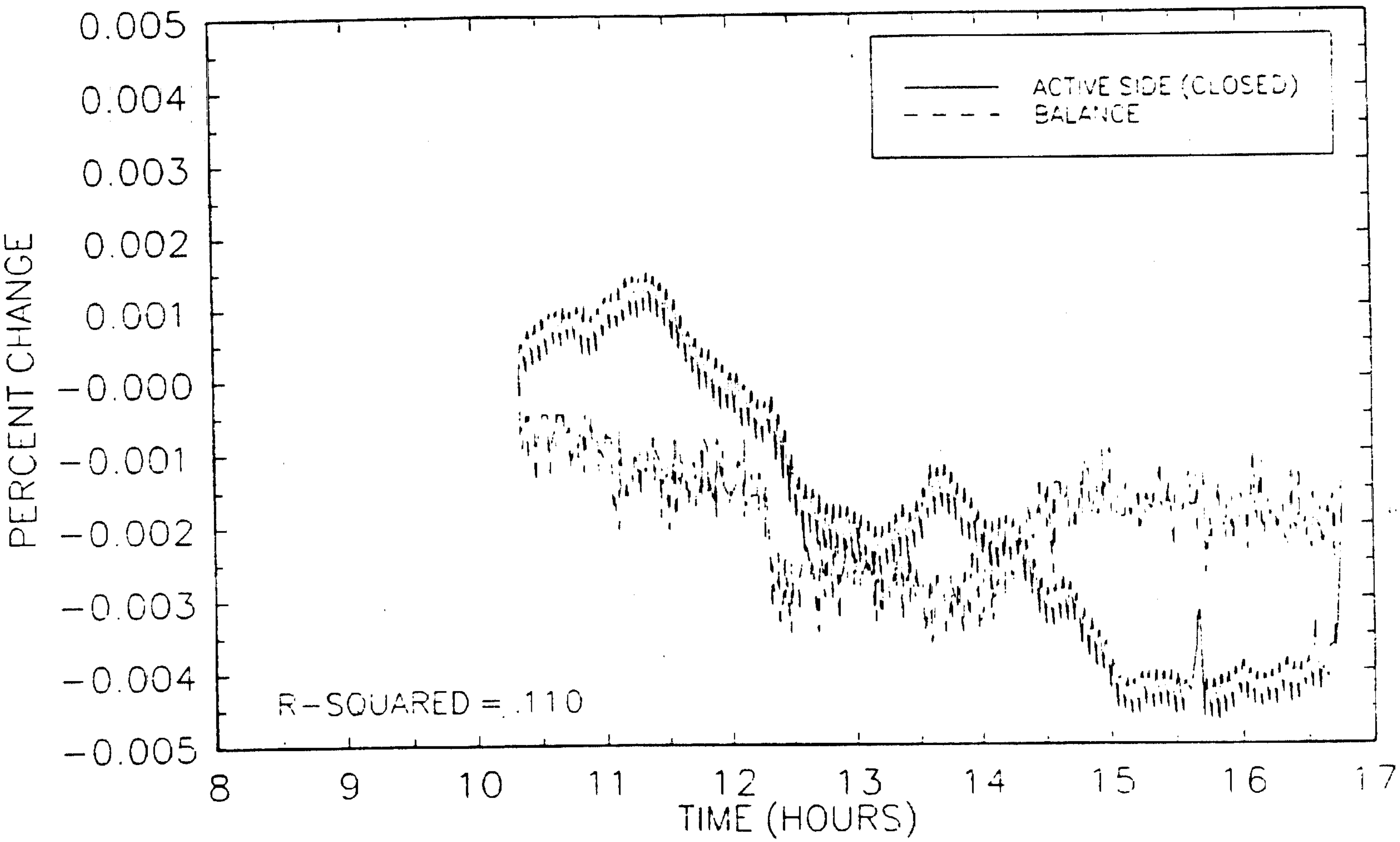
The predicted values were calculated using the coefficients generated from the regression, power measurements vs. the SPM measurements. The analysis removes the effects of the rapid change in solar irradiance from the radiometer measurements. The measurements exhibited the signal stabilization which is expected from a properly operating radiometer (chopped). (See also Figure 14)

FIGURE 16. REGRESSION, POWER OPEN MEASUREMENTS VS. SUN PHOTOMETERS



The predicted values were calculated by using the coefficients generated from the regression, resistance measurements vs. base temperature. The "R-squared" value was .97 indicating a strong correlation between the two parameters.

FIGURE 17. REGRESSION, RESISTANCE VS. BASE TEMPERATURE



The percent change in power readings from the active cavity during shutter closed period and the percent change in the balance measurement. A regression analysis was performed between the power measurements and balance to explain the erratic changes in the power measurements. The regression showed no correlation (R - squared = .11) between two parameters.

FIGURE 18. REGRESSION, POWER CLOSED MEASUREMENTS VS. BALANCE

to determine if the shutter open measurements inability to stabilize during the early morning and late afternoon hours was caused by an instrument problem, or a rapid change in the solar irradiance. The regression was used to remove the effects of a rapid change in the solar irradiance. After the effects were removed, the remaining signal stabilized, indicating the cause of the original instability was a rapid change in solar irradiance. The other two regressions (Figures 17 and 18), resistance vs base temperature and shutter closed (active side) vs balance, were performed to help explain the change in the shutter closed (active side) measurements. The shutter closed active side and inactive side did not change at the same rate over the solar observation day. The shutter closed active side varied more than the inactive side. The shutter closed active side did not vary consistently over all observation days. The regression analysis was an attempt to correlate the change with other parameters but failed to show any significant correlation. The reason for the variation in the closed shutter measurements could be due to the effects of operating the instrument in air.

4.0 DELIVERY OF THE INSTRUMENT

The instrument was delivered to Kennedy Space Flight Center (KSFC) in April 1990, to be integrated with the payload for the ATLAS spacelab mission. The instrument was fully tested at KSFC. Both GSE software (ITE and DAMP) were used for testing the instrument. DAMP software was used for the first time, to test the instrument during the off-line test. The various features of DAMP were demonstrated during these tests. For the testing, the instrument was running in various auto states; especially in AUTO00 which performs all fifteen of the radiometric states. The instrument was also tested with a collimated light source which was placed over the left and right cavities consecutively, and the readings with the shlutter open and shutter closed were noted. The readings were also noted with the light source over the two sunphotometers and the sun monitor. After the off-line testing, the instrument was handed over to KSFC.

5.0 CONCLUSION

The SOLCON software evolved from a purely instrument testing (ITE) software package to a testing, monitoring, and data analysis software program (DAMP). The

DAMP program design was influenced by three important activities: the conversion of the ITE SOVA software to the ITE SOLCON software, the Davos solar comparison, and Earth Radiation Budget Experiment (ERBE) solar calibration data reduction[4,5]. The ITE software conversion provided the foundation for the DAMP program design. The simple calculations and data handling techniques from the ITE software were incorporated into the DAMP. The Davos solar comparison proved to be the most influential activity of all the pre-design activities. The comparison was a field test for the ITE software. This test demonstrated the shortcomings of the ITE software in the areas of data monitoring and data reduction. By reducing solar data in the field, an insight into the SOLCON data reduction techniques and the continuously changing requirements of the PI became apparent. The DAMP program design was also influenced by the ERBE solar monitor data reduction techniques which are similar to SOLCON. The activities which preceded the design of the DAMP program provided the expertise to design a program to handle all data monitoring and data reduction requirements which can be anticipated, and the flexibility to adjust to all unanticipated requirements.

The DAMP program is designed to fulfill the SOLCON testing, data monitoring, and data reduction requirements. The requirements are performed by calculating solar irradiance in real-time, displaying multiple screen overlays, and allowing installable special purpose data reduction modules. The solar irradiance values are the final results from the SOLCON experiment, therefore, by calculating the values in real-time, the results of the experiment can be realized immediately. The validation process of the experiment begins immediately, which allows for quick assessment of the quality of the data. Any peculiarities can be diagnosed in real-time, and the appropriate corrections can be performed. The multiple displays allow the Principle Investigator to monitor only the parameters which are relative to the mode of instrument operation. The displays show information on a basic frame-by-frame overlay, a self calibration overlay, or a solar constant calculation overlay. The ability to adjust to the changing requirements of the Principle Investigator is the DAMP program's strongest forte. The DAMP's facility for managing specialized output modules provides a means to adjust the software to new requirements. The output modules also have the capability to change configuration parameters, giving even more flexibility. The functions that the output module can perform range from simple printing tasks to complex real-time plotting. The ATLAS mission only lasts for 10 days, and the SOLCON experiment is active for approximately 40 hours. Since the experiment is short, and the cost is very high, it is imperative that the GSE software supply the Principle Investigator with all information required for evaluation of the instrument's performance in real-time. The DAMP program provides the information for complete analysis of the SOLCON data in real-time.

REFERENCES

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2. R. B. Lee III, M. A. Woerner, M. A. Gibson, S. Thomas, R. Wilson, July 23-27, 1990, 'Total Solar Irradiance Variability: Five Years of ERBE Data', Seventh Conference on Atmospheric Radiation, San Francisco, California.

3. D. A. Crommelynck, V. Domingo, C. Frohlich, 'Solar Constant and Variability (SOVA)', ESA EURECA Program SOVA User Manual, Doc. Number: UM032, May 1989.

4. D. A. Crommelynck, V. Domingo, 13 July 1984, 'Solar Irradiance Observations', Science, vol. 225, no. 4658, pages 180-181.

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APPENDIX

1.0 DESCRIPTION OF THE GROUND SUPPORT EQUIPMENT (GSE)

The Ground Support Equipment (GSE) is used to store, display, and analyze SOLCON telemetry data. The GSE operates in four modes: Flight, SEID, Replay, and Test. In Flight mode (Figure A-1), the GSE receives telemetry from the SOLCON instrument on the Space Shuttle (or Space Shuttle simulator) over an Experiment Computer Input Output (ECIO) line as explained in Section 2.3.1.1 of the SOLCON User Manual. In Spacecraft Experiment Interface Device (SEID) mode (Figure A-2), the GSE receives telemetry from either SOLCON 2 or a Breadboard over the RS232 line. The Replay mode gives the capability of replaying data that was previously stored in a disk file (Figure A-3). In Test mode (Figure A-4), the GSE can receive data from and send commands to SOLCON 2 (DPU) over an RS232 serial port.

1.1 HARDWARE REQUIREMENTS

The GSE (Figure A-5) is an IBM PC, 286 or 386, or any compatible computer with a specialized computer circuit board (ECIO). This circuit board allows the GSE to communicate with the SOLCON instrument during flight operations. The following are required, or strongly recommended, for the GSE computer.

- 640 KB of RAM	req.
- Hard Disk Drive	req.
- 1 Eight-Bit Full Size Expansion Slot.	req.
- Math Coprocessor	req.
- DOS Version 2.00 or Greater	req.

1.1.1 PERIPHERAL I/O PORTS AND CABLES.

The GSE system requires cables and a printer as follows:

- RS232 Cable Straight Through; 25 db Connectors on Both Ends M-F
- Epson Compatible Printer with Cable
- 2 ECIO Coaxial Cable with Trompeter PL75-9 Connectors
- Power Cable for IBM PC Compatible

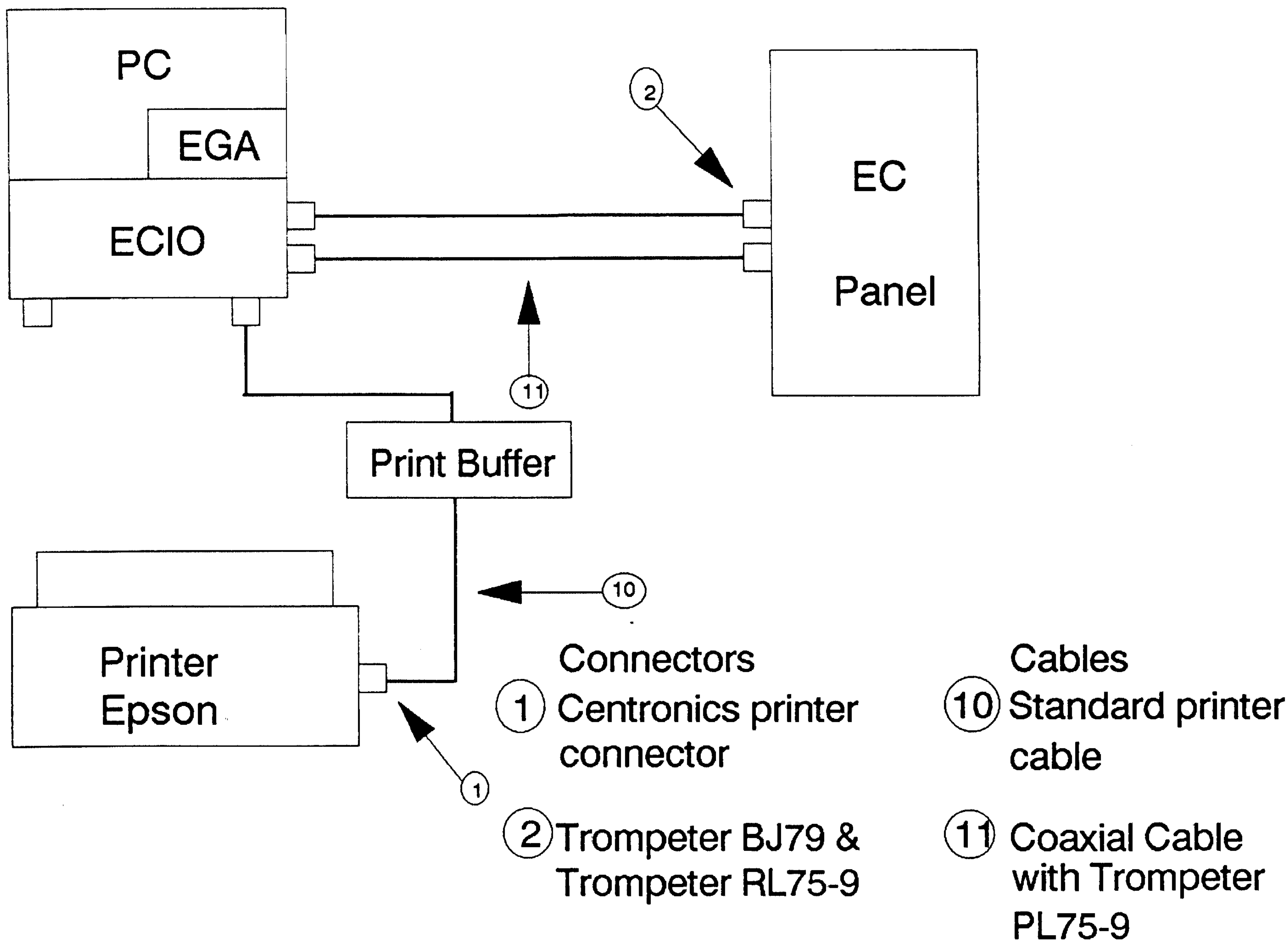


FIGURE A-1. FLIGHT MODE

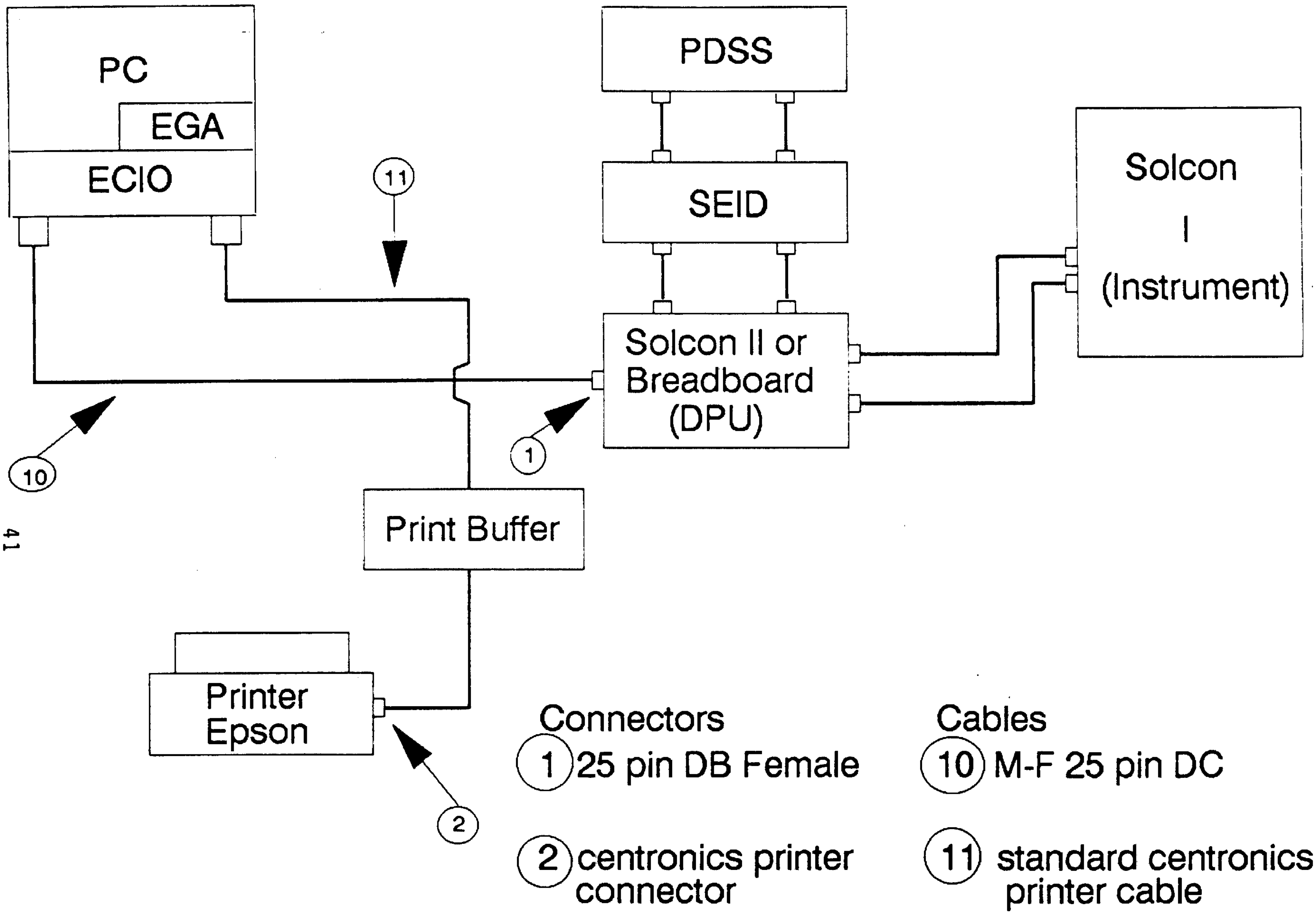


FIGURE A-2. SEID MODE

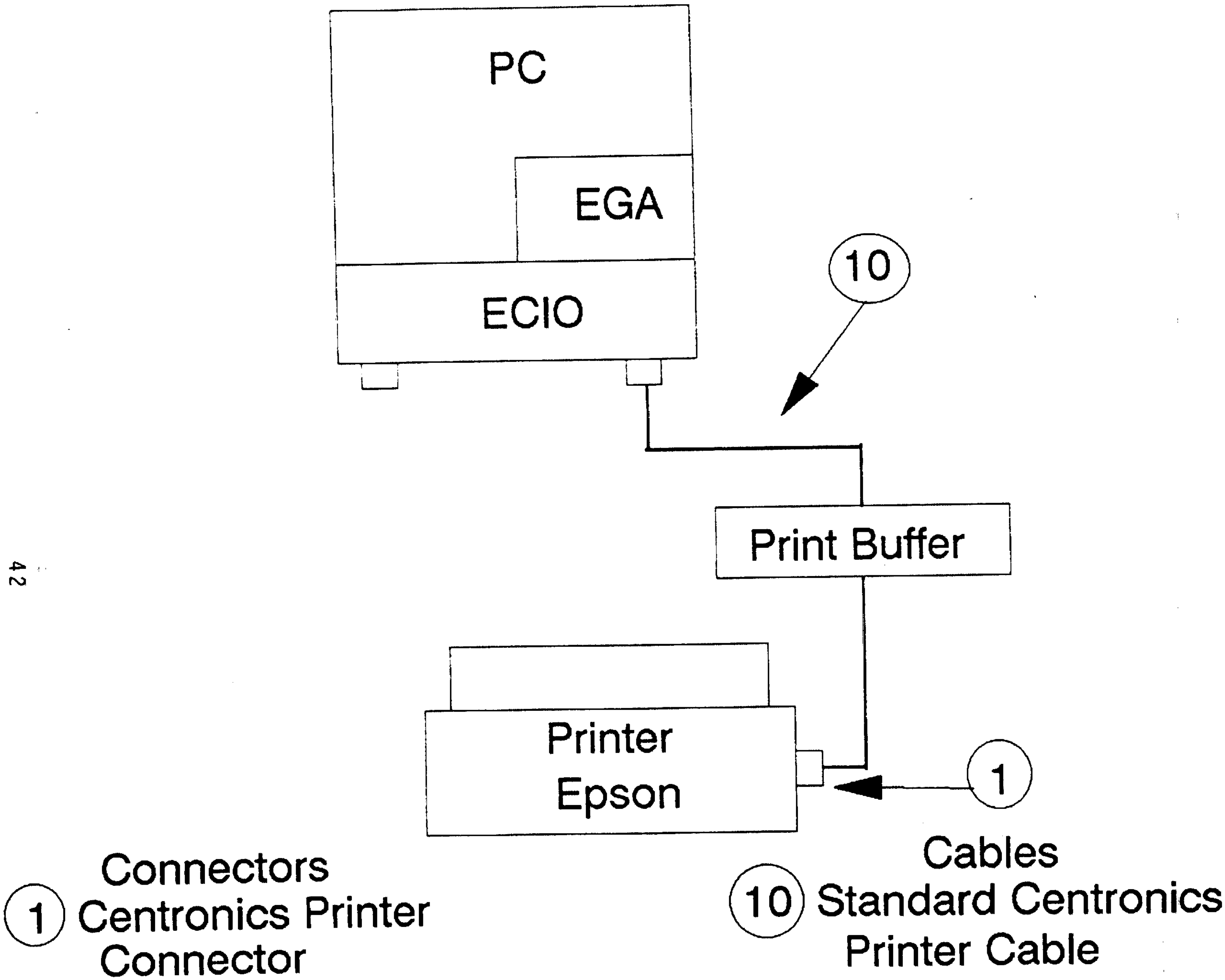


FIGURE A-3. REPLAY MODE

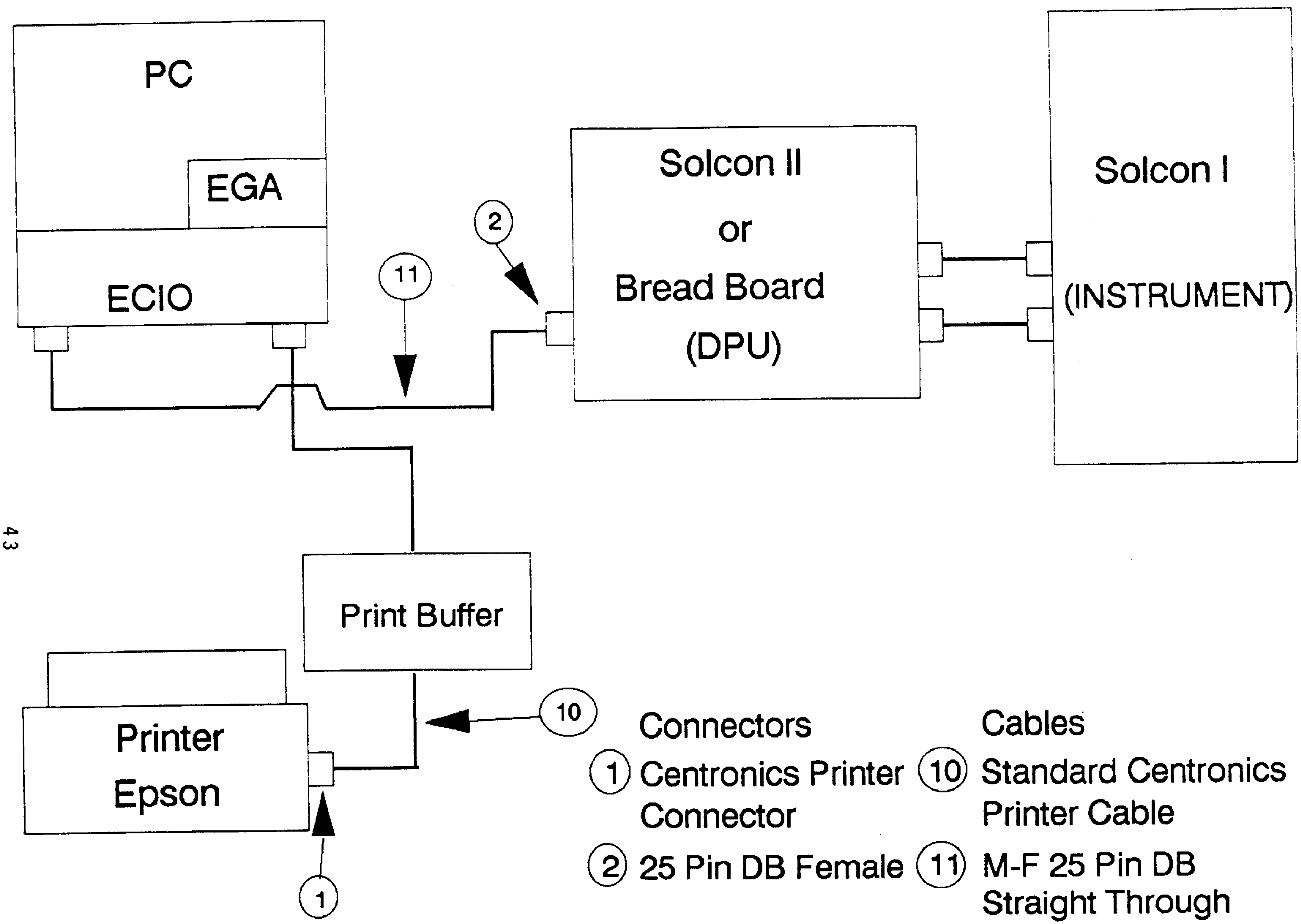


FIGURE 4. TEST MODE

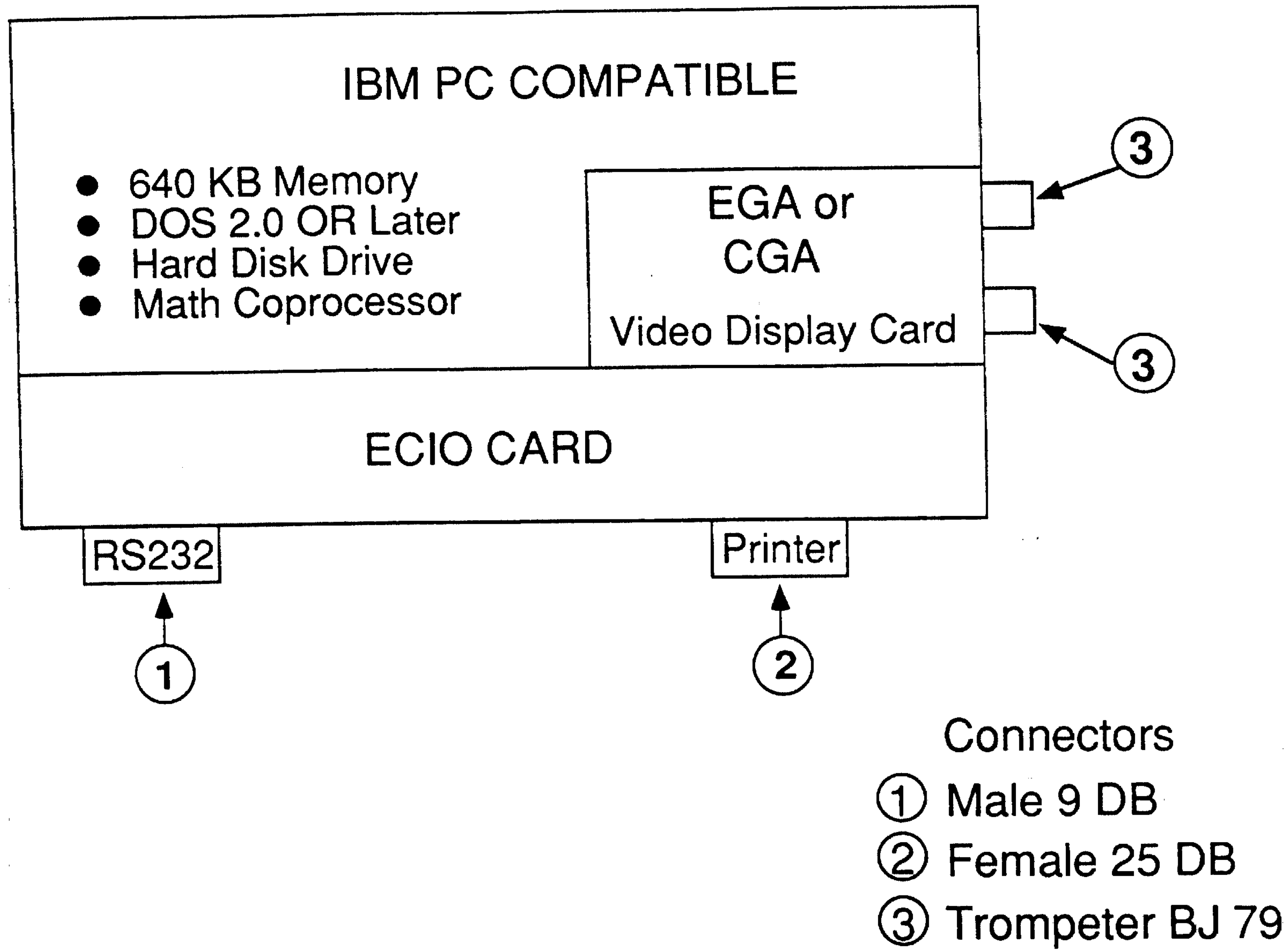


Figure A5. GSE Hardware

1.1.2 POWER SUPPLY

1.1.2.1 DOLCH 386

The Dolch 386 automatically adjusts to European and USA AC power. The only requirement is a power cable that can be plugged into the power source. Power cables can usually be acquired at the work location.

1.1.2.2 Toshiba 1200

The Toshiba 1200 doesn't automatically adjust to European and USA AC power. The Toshiba requires a transformer to adjust the incoming power. Transformers are not readily available at all work locations, so advance planning is required to avoid unnecessary delays.

1.1.3 GRAPHICS ADAPTER AND DISPLAY

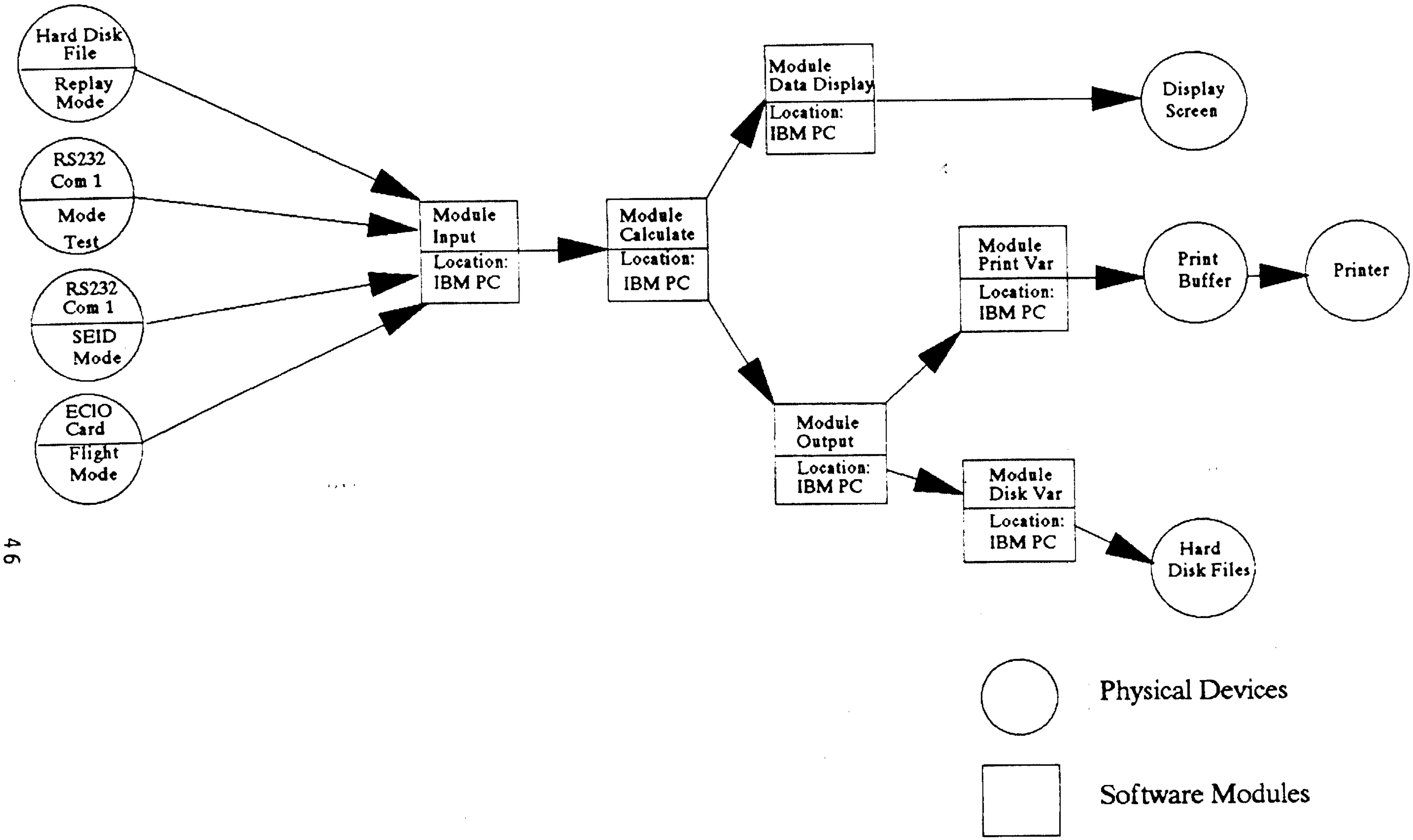
The GSE will work with either a Color Graphics Adapter (CGA) or Enhanced Graphics Adapter (EGA) video adapter. The EGA adapter will provide much clearer screen displays, therefore, it is strongly recommended. A large 19" multisync monitor is recommended for long periods of data monitoring.

2.0 DAMP SOFTWARE

DAMP software was developed to analyze and monitor the data of the SOLCON instrument. There are four modes of operation for DAMP: Flight mode, SEID mode, Test mode, and Replay mode. These modes differ in their input source. Each mode is discussed in detail in Sections 2.6.1 - 2.6.4. The data flow of the DAMP is also given in Figure A-6.

2.1 GENERAL OPERATION OF DAMP SOFTWARE

At the startup of DAMP, initialization of the program is done. The user will be questioned about the type of monitor being used, and the screen will be



The data enter the DAMP program from one of the physical devices located on the left. Upon entering the DAMP program, the data flow through the modules from left to right. The data exit the program through one or more of the output devices located on the right.

FIGURE A-6. DATA FLOW DIAGRAM - DAMP PROGRAM initialized to CGA or EGA mode depending on the user's response. The output to the printer and/or the file will be setup by reading in the definition in output.cnf file. A detailed description of the setup of output.cnf file is given in Sections 2.5, 2.5.1, and 2.5.2.

After the initialization, DAMP is set in a null mode. The user has to select the mode of operation (Flight, SEID, Replay or Test) by hitting the correct command key for input. DAMP receives the data from the input source depending on the mode selected. For all modes other than Replay mode, a file will be opened to collect raw data (see Section 2.4). Depending on the packet type, further action is taken on the input data. If the input is a verification packet, the received information is displayed on the Report/Exception window of the screen. If the science packet is received as input, calculations are done using the data and the converted values are shown on the screen. The calculated values can be sent to the printer and the data file by activating its corresponding slot as in the setup of output.cnf file (see Sections 2.5, 2.5.1, 2.5.2).

DAMP has several associated command keys. A description of each command key used in DAMP is given in Section 2.2. Command keys are issued to select the operation mode, switch between different display screens, send the commands to instrument, and to exit the DAMP.

On exiting DAMP, the screen will be cleared. All output files that are open will be closed. The printer slots which are open will also be closed.

2.2 COMMAND KEYS FOR DAMP

There are several command keys set-up for the operation of DAMP. The command keys are used to activate a particular mode of operation (Flight, SEID, Test, or Replay); set-up different display screens; activate/ deactivate the file and printer slots defined by the output.cnf file (see Sections 2.5, 2.5.1, 2.5.2); and exit the program. Command keys are also set-up to vary the rate at which the input packets are processed and to stop and restart the processing of input packets.

A list of all command keys defined in the DAMP is given in alphabetic order. The action associated with each key is also given.

C - Put the calibration window on the screen

E - Set-up DAMP in Flight mode (ECIO input mode)

F - Put the frame window on the screen

I - Put solarirradiance window on the screen

K - Start/Stop printing error messages (toggle)

M - Set-up command window to send command to the instrument (only in Test mode)

O - Start/Stop the processing of input packets (toggle)

Q - Quit DAMP

R - Set-up DAMP in Replay mode

S - Set-up DAMP in SEID mode

T - Set-up DAMP in Test mode

0..9,
F1..F10 - Enable/Disable slots for the output file and the output to printer (toggle)

UpArrow/
DownArrow - Increase/decrease the input rate

2.3 SCREENS

The screen display for the DAMP software consists of several windows. Some of these windows will be displayed on the screen continuously; others can be overlapped with different windows, depending on user needs.

2.3.1 DEFAULT SCREEN

The default screen (Figure A-7) is the initial display for all the modes. It consists of eight windows. Only the top window will be overlapped with new windows, the rest will be displayed at all times.

```
Frame# Vh_L   Cur_L  SPM1    PowL   ResL   Cbal ResR   PowR   SPM2   Cur_R  Vh_R
---------------------------------------------------------------------------------
0      ****************************************** **************************************
1      *************** 2.0285************** 6340*************** 2.6157**************
2      *************** 2.0304************** ******************* 2.6185**************
3        3.972 33.143 2.0300 131.66 119.86 6337 119.83 131.91 2.6178 33.178 3.976
4        3.972 33.143 2.0305 131.66 119.86 **** 119.83 131.92 2.6191 33.180 3.976
5        3.972 33.143 2.0309 131.66 119.85 6340 119.83 131.92 2.6197 33.180 3.976
6      *************** 2.0315************** ******************* 2.6206**************
7        3.972 33.143 2.0308 131.66 119.86 6337 119.83 131.94 2.6195 33.182 3.976
8        3.972 33.143 2.0302 131.66 119.86 **** 119.83 131.93 2.6190 33.181 3.976
9        3.972 33.143 2.0315 131.66 119.86 6336 119.83 131.92 2.6207 33.180 3.976
10       3.972 33.143 2.0306 131.66 119.86 **** 119.83 131.93 2.6196 33.180 3.976
11       3.972 33.143 2.0317 131.66 119.86 6338 119.83 131.93 2.6210 33.180 3.976
         3.972 33.143 2.0300 131.66 119.86 6342 119.82  59.07 2.6175 22.203 2.660
---------------------------------------------------------------------------------
         0.000  0.000 0.0016   0.00   0.00    4   0.02  72.86 0.0035 10.978 1.316
---------------------------------------------------------------------------------
09:13:13       23:52:05     05-10-89     RAD 6      AUTO10     nC     Dok     Sok
---------------------------------------------------------------------------------

_________________________________________________________________________________
Command Echo                                 :
AUTO10                                       :
                                             :
                                             :12:42:30  BAL:range error
---------------------------------------------------------------------------------
      :Status :Command :    Temperature      :  Sun Values      :Mode: Replay
Cover :error  :close   :  12.25          9.91 :Alpha     0.47   :  1  2  3  4
Lsh   :close  :close   :        41.56         :Beta     -0.07   :  5  6  7  8
Rsh   :close  :close   :                      :Angle     0.48   :  9 10 11 12
Sside :right  :right   :   9.71          9.79 :    Mux Values   : 13 14 15 16
Sstat :1      :1       :        12.88         :MUX1-4    0.00   : 17 18 19 20
Ref   :1      :1       :                      :Mux5      2.00   :Print err: On
Bal   :0      :0       :  21.32         23.79 :Mux6      2.00   :
```

FIGURE A-7. DEFAULT SCREEN DISPLAY

The first window on the screen, called the Frame Window, displays the information of several frames. The first line is the header line. Lines 2 to 13 represent the frames of the current cycle. The new cycle starts after every 98 seconds. As a new cycle starts, lines 2 to 13 will be cleared. The first frame of the current cycle will be displayed at line 13. As additional frames come in every 8 seconds, the lines will scroll up. Line 14 is the last frame from the previous cycle. The last line in this window is the difference of the current frame and the last frame from the previous cycle (i.e. Line 13 and Line 14). The first item on each line is the frame number. This is followed by the heater signals of the radiometers and the sunphotometer readings. The left part of the screen shows the signals from the left heater and SPM1, and the signals from the right heater and SPM2 are shown on the right side. The coarse balance signal is displayed in the center of the line. The list of the displayed parameters and their units are as follows:

Frame	:	Frame number
VhL	:	Voltage of the left heater, Volts
CurL	:	Current on the left heater,mA
SPM1	:	Reading on the sunphotometer 1, Volts
PowL	:	Power on the left side, mW
ResL	:	Resistance of the left heater, ohms
CBAL	:	Coarse balance
ResR	:	Resistance of the right heater, ohms
PowR	:	Power on the right side, mW
SPM2	:	Reading on the sunphotometer 2, Volts
CurR	:	Current on the right heater,mA
VhR	:	Voltage of the right heater, Volts

If a value is not present in the current frame, asterisks (****) are shown in its position.

The second window contains a single line. It starts with the time of the last update of the screen followed by the DPU time; the time from the last SOLCON frame received. It also displays the date, the current radiometric state(RADxx), the autosequence number(AUTOxx), the calibration indicator(nc for normal and ec for extended), the data flag (Dok for good data or Div for bad data), and the status of the sun (Sok for 'sun-in-view' or Sno for 'no sun') respectively.

Below the second window comes in the command window. The command window is set-up to send the command to the instrument in the test mode. When the key to send the command is issued (see Section 2.2), the command window will display a prompt to enter the instrument command. The command entered by the user is also echoed on the command window. The end of the command is denoted by hitting carriage return (<cr>). The command window is also used when a warning error occurs within DAMP. This is to get the response from the user whether to terminate the program.

The next line of windows is the Report/Exception window on the left and the Error window on the right. The Report/Exception window will display all the verification packets received from the instrument. The verification packets include the Report packets and the Command Echo packets. The first line on the window will display the type of the packet (Report/Exception or Command Echo). The error window is set-up for displaying all the errors that appear in the received science data. The error window will scroll up as new error messages come in.

The lower left hand corner window is the status window. It displays the commands given, which is determined from the current radiometric state, and the actual status for cover, left shutter(Lsh), right shutter(Rsh), servoside(SSide), servostate (SStat), Balance(Bal), and Reference(Ref). The first column gives the name of each position, the second column shows the commands given and the third column is the corresponding status.

The middle window in the last row is the Temperature window. The temperatures are shown in degree centigrade. The geometrical arrangement is shown below.

T1		T7
	T8	
T2		T3
	T6	
T5		T4

The first row of the temperature display is the left and right shutter temperatures (T1 & T7). The center row is the left(T2) and right (T3) aperture temperatures, and last row shows the electronic temperatures (T5 & T4). The two values in the center column are the photometer (T8) and base (T6) temperatures.

The window immediately to the right of temperature window displays the sunmonitor information and the multiplexer (MUX) values. The horizontal and vertical axes values and angle of the sun are displayed as the sun monitor data. The MUX values for channels 1 - 4, channel 5, and channel 6 are the MUX values shown at the bottom.

The window in the right-most corner is set up to display the status of the DAMP. The mode in which DAMP is running, the number associated with each output slot that is currently activated, and the status of the printer in regard to printing error messages (ON/OFF) is displayed in this window.

2.3.2 OVERLAP WINDOWS

The frame window can be overlapped with two other windows: the Calibration window and the Solar Irradiance window.

2.3.2.1 <u>Calibration Window</u>

The Calibration window is shown in Figure A-8. It displays the calculated calibration voltages V1 through V6 for all six channels (see Sections 2.1.4 and 2.1.6 of SOLCON User Manual). Whenever a new calibration voltage is calculated, the value displayed in position 'Current' will be moved to the position 'Last', and the new value will be displayed at the 'Current' position. The difference between the two values is shown at the position 'Diff'.

```
      :          :   V1    :   V2    :   V3    :   V4    :   V5    :   V6    :
      :Current   : 3.53788 : 3.17603 : 2.80350 : 2.44152 : 2.06905 : 1.70664 :
Chan1 :Last      : 3.53794 : 3.17605 : 2.80353 : 2.44150 : 2.06904 : 1.70666 :
______:Diff______:_0.00006_:_0.00002_:_0.00003_:_0.00002_:_0.00000_:_0.00002_:
      :Current   : 3.53783 : 3.17601 : 2.80347 : 2.44150 : 2.06905 : 1.70661 :
Chan2 :Last      : 3.53793 : 3.17603 : 2.80349 : 2.44149 : 2.06905 : 1.70663 :
______:Diff______:_0.00010_:_0.00002_:_0.00002_:_0.00000_:_0.00001_:_0.00002_:
      :Current   : 4.24573 : 3.80430 : 3.36794 : 2.92656 : 2.49023 : 2.04876 :
Chan3 :Last      : 4.24575 : 3.80432 : 3.36794 : 2.92653 : 2.49021 : 2.04877 :
______:Diff______:_0.00002_:_0.00002_:_0.00000_:_0.00003_:_0.00001_:_0.00001_:
      :Current   : 4.24569 : 3.80429 : 3.36791 : 2.92655 : 2.49023 : 2.04874 :
Chan4 :Last      : 4.24574 : 3.80431 : 3.36793 : 2.92653 : 2.49022 : 2.04876 :
______:Diff______:_0.00006_:_0.00002_:_0.00002_:_0.00002_:_0.00001_:_0.00002_:
      :Current   : 4.24509 : 3.80377 : 3.36755 : 2.92624 : 2.49007 : 2.04856 :
Chan5 :Last      : 4.24516 : 3.80388 : 3.36761 : 2.92628 : 2.49008 : 2.04861 :
______:Diff______:_0.00007_:_0.00011_:_0.00005_:_0.00004_:_0.00001_:_0.00005_:
      :Current   : 3.53743 : 3.17562 : 2.80322 : 2.44125 : 2.06891 : 1.70649 :
Chan6 :Last      : 3.53748 : 3.17569 : 2.80328 : 2.44129 : 2.06893 : 1.70654 :
______:Diff______:_0.00005_:_0.00007_:_0.00005_:_0.00004_:_0.00002_:_0.00005_:
09:59:17      00:30:11    05-10-89     RAD 6      AUTO10     nC      Dok     Sok
---------------------------------------------------------------------------------
_________________________________________________________________________________
Command Echo                            :
AUTO10                                  :
                                        :
                                        :13:43:00  BAL:range error
---------------------------------------------------------------------------------
     :Status :Command :  Temperature      :  Sun Values      :Mode: Replay
Cover :error :close   :  15.08     12.72 :Alpha     0.45    :  1  2  3  4
Lsh   :close :close   :       43.56      :Beta     -0.06    :  5  6  7  8
Rsh   :close :close   :                  :Angle     0.45    :  9 10 11 12
Sside :right :right   :  11.94     12.05 :   Mux Values     : 13 14 15 16
Sstat :1     :1       :       14.81      :MUX1-4    0.00    : 17 18 19 20
Ref   :1     :1       :                  :Mux5      2.00    :Print err: On
Bal   :0     :0       :  23.07     25.83 :Mux6      2.00    :
```

FIGURE A-8. SCREEN DISPLAY WITH CALIBRATION WINDOW

2.3.2.2 Solar Irradiance Window

The Solar Irradiance window, shown in Figure A-9, will display the calculated value for solar irradiance and the values used for its calculation. The first line in the window is the header line. On the left side of the window, the power and status values of the instrument for last three radiometric states is displayed, i.e. two closed states and one open state of the shutter. In each of these Sections, the power calculated for the last five frames in the cycle is shown. This is followed by the values used for the calculation of solar irradiance. Fifteen sets of values will be shown in the window. When the window becomes full, it will scroll up. The values in each set are as follows: Power when shutter is in open state (Popen), average value of power for closed states before and after the open state (Pclose), the difference between power-open and power-close (Pdiff), temperature of the aperture (Taper), temperature of the shutter (Tshtr), correction factor due to the temperatures (Corr), angle of the sun (Angle), and the calculated solar irradiance value (SI).

2.4 DATA STORAGE

The raw data are stored in a disk file for Flight, SEID, and Test modes. The disk file name is created automatically with format yyMMddhh.mmz, where,

yy - year
MM - month
dd - day
hh - hour
mm - minute
z - a,b,c etc. A new file is created every 130 KB.

A sample file name is 87032310.07b. This file was created by a GSE session at 10:07 on March 23, 1987, and is the second file created for the session. The format of the disk file is as follows:

Block length (2 bytes in DEP format
(Section 2.2.4.2.1 of SOLCON User Manual))

```
      |Power     Stat  | Popen| Pclos|Pdiff | Taper| Tshtr| Corr   | Angle| SI    |
---------------------------------------------------------------------------------
      |   131.70 Error | 53.71|131.70| 78.00| 13.55| 14.31|*******|  0.45|*******|
      |   131.69 Error | 53.46|131.69| 78.23| 13.78| 14.62|*******|  0.44|*******|
Close |   131.69 Error | 53.22|131.67| 78.45| 14.02| 14.93|*******|  0.44|*******|
      |   131.70 Error | 53.10|131.66| 78.55| 14.28| 15.30|*******|  0.44|*******|
______|___131.70_Error | 52.87|131.64| 78.77| 14.54| 15.63|*******|  0.44|*******|
      |    51.69 Error | 52.68|131.62| 78.94| 14.82| 15.96|*******|  0.44|*******|
      |    51.66 Error | 52.56|131.61| 79.06| 15.09| 16.19|*******|  0.44|*******|
Open  |    51.65 Error | 52.42|131.61| 79.19| 15.37| 16.46|*******|  0.44|*******|
      |    51.66 Error | 52.29|131.62| 79.33| 15.64| 16.68|*******|  0.44|*******|
______|____51.65_Error | 52.24|131.63| 79.39| 15.91| 16.93|*******|  0.44|*******|
      |   131.72 Error | 52.25|131.65| 79.40| 16.17| 17.13|*******|  0.44|*******|
      |   131.71 Error | 52.24|131.66| 79.42| 16.42| 17.35|*******|  0.44|*******|
Close |   131.71 Error | 52.09|131.67| 79.58| 16.66| 17.52|*******|  0.44|*******|
      |   131.72 Error | 51.82|131.69| 79.86| 16.89| 17.72|*******|  0.44|*******|
______|___131.72_Error_|_51.66|131.71|_80.04|_17.12|_17.86|*******|__0.44|*******|
11:08:22       01:47:21      05-10-89       RAD 6        AUTO10     nC    Dok    Sok
---------------------------------------------------------------------------------

---------------------------------------------------------------------------------
Command Echo                              |
AUTO10                                    |
                                          |
                                          |13:43:00  BAL:range error
---------------------------------------------------------------------------------
       |Status  |Command |     Temperature      |  Sun Values      |Mode: Replay
Cover  |error   |close   |  20.21         17.86 |Alpha     0.43    |  1  2  3  4
Lsh    |close   |close   |         47.33        |Beta     -0.06    |  5  6  7  8
Rsh    |close   |close   |                      |Angle     0.44    |  9 10 11 12
Sside  |right   |right   |  16.95         17.12 |    Mux Values    | 13 14 15 16
Sstat  |1       |1       |         19.38        |MUX1-4    0.00    | 17 18 19 20
Ref    |1       |1       |                      |Mux5      2.00    |Print err: On
Bal    |0       |0       |  27.40         30.43 |Mux6      2.00    |
```

FIGURE A-9. SCREEN DISPLAY WITH SOLAR IRRADIANCE WINDOW

TM packet (up to 50 Bytes)

Time Stamp (3 bytes in Modula-2 Format)

NOTE: Block length does not include time stamp.

See Figure A-10 for an example.

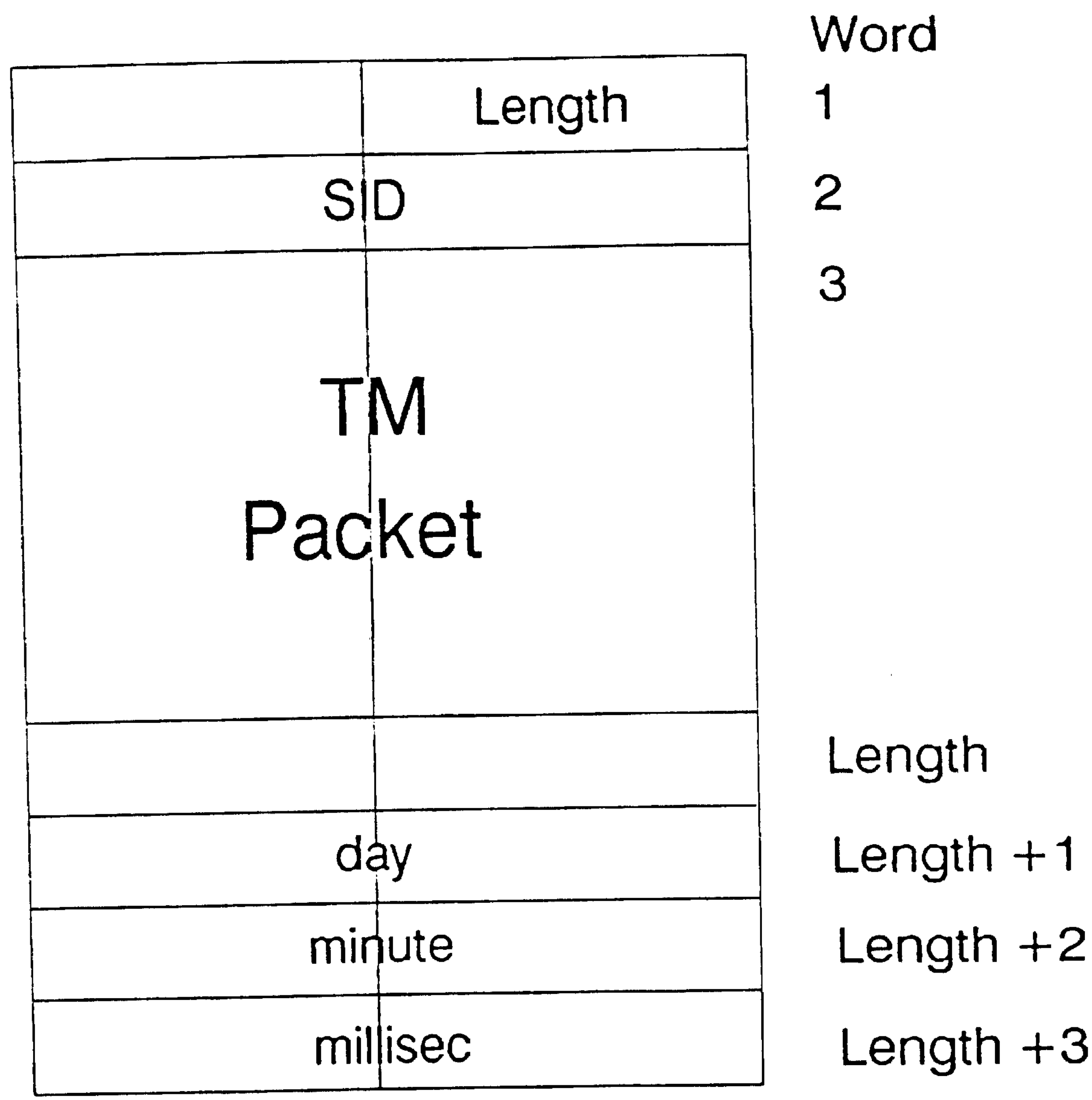
2.5 OUTPUT

The current output capabilities include sending reduced data to either the printer or to files. A configuration file (OUTPUT.cnf) allows the user to setup multiple formats and destinations (file or printer) for sending processed output. Each user defined format and destination is called a slot. The slots can be activated and deactivated at anytime during program execution. The user can control what (variables), when (by disable/enable slots), where (printer or file), and how (formats) the data is output. The configuration file can be edited by any text editor. The OUTPUT.cnf must be present to execute the DAMP program. A sample of the OUTPUT.cnf file is given in Figure A-11.

2.5.1 PRINTER OPTION

The DAMP program provides a very versatile print capability; it has the ability to print any specified variable at the specified interval. The user specifies the variables to be printed through the configuration file. The configuration file is divided into slots. Each slot characterizes a printer page format. The format consists of the following:

Module Name	The actual name of the Modula-2 module to be executed. Currently there is only one for printing, this is 'PrintVarMain'.
Title	The user defined slot title to be displayed at the top of each page along with the date, time, and page number.
Interval	The number of frames to skip before printing next line of output.



Note: Length is in the Last five bits of word 1.

FIGURE A-10. DATA PACKET STRUCTURE

```
key 1
******
PrintVarMain
LEFT SIDE
1
Soltime       frameNum   CurL             VhL         PowL
Time_Wall      Frame       Curr_Left     Volt_Left  Power_Left
HH:MM:SS        num          mA             Volt        mW
xxxxxxxx  xx.  xxx.xx   x.xxxxx   xxx.xx

key 2
******
PrintVarMain
RIGHT SIDE
12
Soltime       frameNum   CurR             VhR         PowR
Time_Wall      Frame       Curr_Right    Volt_Right Power_Right
HH:MM:SS        num          mA             Volt        mW
xxxxxxxx  xx.    xxx.xx   x.xxxxx   xxx.xx

key 3
******
DiskVarMain
Temps
24
Soltime      frameNum T1   T2  T3  T4  T8
wall     Frame        Temp_1  Temp_2  Temp_3  Temp_4  Temp_8
xxxxxxxx  xx.     xx.xx     xx.xx    xx.xx    xx.xx    xx.xx
```

Figure A-11. OUTPUT.CNF File

Variable Names	The actual name of the variable to be printed (the names used inside the program). See the list at the end of this Appendix.
Variable Title	The title for each variable that the user wishes to appear at the top of each page.
Units	The units of each variable that the user wishes to appear under each Variable Title.
Format	The format describes the exact placement of each variable on a particular output line. This can be in real or character form.

In Figure A-11, there is an example of OUTPUT.cnf. In this example, there are two printer slots specified LEFT SIDE and RIGHT SIDE. They both use the module PrintVarMain to spool characters to the printer. LEFT SIDE has an interval setting of one, therefore, a line of output will be printed for every frame. Since RIGHT SIDE has an interval setting of twelve, a line will be printed every twelfth frame. The variable names specified are taken from the list at the end of this Appendix. The variable names must have at least one space separating them. There must be one variable title, unit, and format specified for each variable name. The user defined variable titles must have at least one space separating them. The titles are automatically centered around their corresponding format. The units must have at least one space separating them. The units are automatically centered around their corresponding format. The format describes the position of each printed variable and the number of characters or digits to print. The format line is limited to 130 characters. For example, under LEFT SIDE, variable name CURL will be displayed as the third variable with three digits before and two digits after the decimal point. If CURL is too large for the format described, then it is displayed as '000000'. To display characters such as TIMEW, the format should contain enough "x's" to display the entire string. Truncation will occur if there are an insufficient number of "x's" defined for characters. The configuration file is read in during program initiation. The configuration file can be modified using any text editor. After initiation, the slots may be activated and deactivated from the keyboard. Figure A-12 shows the output generated by the OUTPUT.cnf. Notice that some areas contain xxxx.xx instead of numbers. "X's" are displayed when new values are not available for printing.

2.5.2 FILE OPTION

Sometimes detailed data analysis is required to be performed on SOLCON data. The DAMP software permits storage of data in ASCII files which later can be read into a spreadsheet. The user specifies variables to be dumped to the output file by setting up the configuration file. The configuration file is divided into slots. Each slot characterizes a line of output in the dump file. The format consists of the following:

Module Name	The actual name of the Modula-2 module to be executed. Currently there is only one for files, this is 'DiskVarMain'.
Title	The user defined slot title is used as the file name.
Interval	The number of frames to skip before dumping the next line of output.
Variable Names	The actual name of the variable to be dumped (the name used inside the program). See the list at the end of this Appendix.
Variable Title	The user defined title of each variable which will appear at the top of the dump file.

LEFT SIDE

90-11-05 10:50:54 PAGE: 1

Time_Wall	Frame	Curr_Left	Volt_Left	Power_Left
HH:MM:SS	num	mA	Volt	mW
23:15:51	11	33.08	3.96428	131.12
23:15:59	12	xxx.xx	x.xxxxx	xxx.xx
23:16:07	13	xxx.xx	x.xxxxx	xxx.xx
23:16:16	14	xxx.xx	x.xxxxx	xxx.xx
23:16:24	15	33.07	3.96411	131.11
23:16:32	16	33.08	3.96445	131.14
23:16:40	17	33.08	3.96430	131.12
23:16:49	18	xxx.xx	x.xxxxx	xxx.xx
23:16:57	19	33.08	3.96432	131.13
23:17:05	20	33.08	3.96440	131.13
23:17:13	21	33.08	3.96430	131.13
23:17:21	22	33.08	3.96438	131.13
23:17:30	23	33.08	3.96447	131.14
23:17:38	0	xxx.xx	x.xxxxx	xxx.xx
23:17:46	1	xxx.xx	x.xxxxx	xxx.xx
23:17:54	2	xxx.xx	x.xxxxx	xxx.xx
23:18:03	3	33.08	3.96423	131.12
23:18:11	4	33.08	3.96451	131.14
23:18:19	5	33.08	3.96448	131.14
23:18:27	6	xxx.xx	x.xxxxx	xxx.xx
23:18:36	7	33.08	3.96433	131.13

FIGURE A-12. PRINTER OUTPUT

Format The format describes the exact placement of each variable on a particular line. This can be in real or character form.

In Figure A-11, there is an example of OUTPUT.cnf. In this example, there is one dump file slot specified TEMPS. TEMPS uses the module DiskVarMain to dump characters to the file. TEMPS has an interval setting of 24; therefore, a line will be dumped every 24 frames. The variable names specified are taken from the list in the end of this Appendix. The user defined variable names must have at least one space separating them. There must be one variable title, and format specified for each variable name. The variable titles must have at least one space separating them. The titles are automatically centered around their corresponding format. The format describes the position of each dumped variable and the number of characters or digits to display. The format line is not limited in length. For example, under Temp_1 variable name, Temperature-1 will be displayed as the third variable with two digits before and two digits after the decimal point. If Temperature-1, which is a real, is too large for the format described, then it is displayed as '0000000'. To display characters such as TIMEW (a character string), the format should contain enough "x's" to display the entire string. Truncation will occur if there are an insufficient number of "x's" defined. The configuration file is read in during program initiation. The configuration file can be modified using any text editor. After initiation, the slots may be activated and deactivated from the keyboard. Figure A-13 shows the file generated by the OUTPUT.cnf configuration file. Notice that some areas contain xxxx.xx instead of numbers. "X's" are displayed when new values are not available for dumping.

2.6 MODES OF OPERATION FOR DAMP

2.6.1 FLIGHT MODE

Flight mode can be invoked by issuing the command key, 'E'. During flight, the input source for DAMP is the ECIO card. The ECIO card will receive the SOLCON

wall	Frame	Temp_1	Temp_2	Temp_3	Temp_4	Temp_8
23:17:38	0	10.70	8.68	8.74	22.77	41.55
23:20:56	0	10.81	8.74	8.80	22.85	41.55
23:24:13	0	10.93	8.79	8.85	22.94	41.55
23:27:31	0	11.07	8.86	8.92	23.03	41.55
23:30:48	0	11.21	8.94	9.00	23.12	41.55
23:34:06	0	11.32	9.02	9.09	23.21	41.55
23:37:24	0	11.44	9.12	9.19	23.30	41.55
23:40:41	0	11.56	9.21	9.28	23.44	41.56
23:43:59	0	11.79	9.39	9.47	23.53	41.56
23:47:16	0	11.92	9.49	9.57	23.63	41.56
23:50:34	0	12.07	9.60	9.68	23.73	41.56
23:53:52	0	12.25	9.71	9.79	23.85	41.56
23:57:09	0	12.44	9.84	9.92	23.97	41.55
00:00:27	0	12.60	9.97	10.06	24.08	41.64
00:03:44	0	12.76	10.11	10.19	24.21	41.78
00:07:02	0	12.93	10.25	10.33	24.34	41.93

FIGURE A-13. DISK FILE OUTPUT

data through the Experiment Ground Support Equipment(EGSE) stream. The description and the operation of the ECIO card is given in Section 2.3.1.1 of the SOLCON User Manual. The received data is placed in the ring buffer of input data. The raw data file is created in this mode.

Flight mode is passive, so the commands cannot be sent to the instrument in this mode. In this mode, the valid keys are those related to screens and to the output. They are C, F, I, K, O, Q, 0..9, and F1..F10 (see Sections 2.2, 2.3, and 2.5).

2.6.2 SEID MODE

The Spacecraft Experiment Interface Device (SEID) mode is designed to display SOLCON TM data whenever the SEID is being used to command the SOLCON instrument. SEID mode is invoked by issuing the command key 'S'. The data is received over the RS232 line in a passive mode i.e. the DAMP only receives data. The commands, screens, printer options, and file options are the same as in flight operations (see Sections 2.2, 2.3, 2.5, and 2.6.1). The RS232 configuration is as follows:

COM PORT #1 on GSE

- 9600 Baud Rate
- 8-Bit Data
- No Parity

The input format to the DAMP is in the form of a Send Serial packet as described in Section 2.2.4.2.5 of the SOLCON User Manual.

NOTE: Nothing is ever sent to the DPU from the DAMP in this mode.

2.6.3 REPLAY MODE

The Replay mode replays the data files which are created whenever the DAMP program runs. The input format is described in Section 2.4. The user can invoke the Replay mode by the command key 'R'. When entering this mode, the user will be asked:

INPUT FILE NAME:

At this prompt the user should enter a valid data input file name.

DELAY (in 10 ms):

At this, the user is allowed to change the rate at which data is read from a file. (eg. enter '5' to delay 50 ms between each packet). The commands, screens, printer options, and file option are the same as in flight operations, (see Sections 2.2, 2.3, 2.5, and 2.6.1).

2.6.4 TEST MODE

The Test mode is invoked by the command key, 'T'. Commands are sent to the instrument only in this mode. The communication between the DAMP and the instrument is through the RS232 line connected to COMPORT 1 of the GSE. All the command keys, except the mode changing keys, are valid in test mode. The screen, printer, and the file options are the same. The raw data file is created in this mode.

3.0 GSE SOFTWARE PROCEDURES

This Section describes installation, compiling, linking, and execution procedures for DAMP.

3.1 INSTALLATION

The DAMP program is delivered on two 720 KB diskettes. To install:

- Place DAMP Disk 1 into A: Drive.
- Change to the Target Hard Drive
- Type A:INSTALL <CR>

This will do the following:

- Make the Directory \damp
- Copy Disk 1 and 2 to Directory \damp
- Instruct the User to Modify their CONFIG.SYS to Include
  FILES=20
  BUFFERS=20

Now the DAMP program is ready to run, see Section 3.4 .

3.2 COMPILING

The DAMP program can be compiled by executing COMPDAMP. The DAMP program requires a Logitech Modula-2 version 3.03 compiler to be installed with the autoexec.bat and config.sys files configured as described in Section 3.1 .

COMPDAMP.bat performs the following functions:

- compiles all DAMP modules.

3.3 LINKING

The DAMP program can be linked by executing LINKDAMP. The DAMP program requires a MS DOS Linker and HALO88 Version 1.00.13 to be installed with the autoexec.bat and config.sys files configured as described in Section 3.1 .

LINKDAMP performs the following functions:

- Link the DAMP Program "link damp+halodvxx,,,halom2/map"

3.4 EXECUTION PROCEDURES

DAMP program is executed by invoking the batch file DAMP. The batch file will start the execution of the program DAMP.

DAMP Program Variable Name List

NAME	DESCIPTION	UNITS	FORMAT	TYPE
CurL	current left side	mA	x.xxx	REAL
CurR	current right side	mA	x.xxx	REAL
VhL	voltage left side	volts	x.xxx	REAL
VhR	voltage right side	volts	x.xxx	REAL
SPM1	sun photometer 1	volts	x.xxx	REAL
SPM2	sun photometer 2	volts	x.xxx	REAL
ResL	resistance left side	ohms	xxx.xxxx	REAL
ResR	resistance right side	ohms	xxx.xxxx	REAL
PowL	power left side	mW	xxx.xxx	REAL
PowR	power right side	mW	xxx.xxx	REAL
SA	sun monitor A quad.	counts	xxxxxx.	REAL
SB	sun monitor B quad.	counts	xxxxxx.	REAL
SC	sun monitor C quad.	counts	xxxxxx.	REAL
SD	sun monitor D quad.	counts	xxxxxx.	REAL
T1	left shutter temp.	deg. C	xx.xx	REAL
T2	left aperture temp.	deg. C	xx.xx	REAL
T3	right aperture temp.	deg. C	xx.xx	REAL
T4	electronic temperature	deg. C	xx.xx	REAL
T5	electronic temperature	deg. C	xx.xx	REAL
T6	base temperature	deg. C	xx.xx	REAL
T7	right shutter temp.	deg. C	xx.xx	REAL
T8	photometer temperature	deg. C	xx.xx	REAL
Cbal	course balance	counts	xxxx.	REAL
Mux4	Multiplier 0 - 3	counts	x.	REAL
Mux5	Multiplier 5	counts	x.	REAL
Mux6	Multiplier 6	counts	x.	REAL
Pitch	pitch angle	degrees	x.xxx	REAL
Roll	roll angle	degrees	x.xxx	REAL
Angle	roll by pitch	degrees	x.xxx	REAL
Sum	sum of all quads.	counts	xxxxx.	REAL

NAME	DESCRIPTION	UNITS	FORMAT	TYPE
Radst	radiometric state	2-16	xx.	REAL
V1ch1	volt 1 chan. 1	volts	x.xxxxxx	REAL
V2ch1	volt 2 chan. 1	volts	x.xxxxxx	REAL
V3ch1	volt 3 chan. 1	volts	x.xxxxxx	REAL
V4ch1	volt 4 chan. 1	volts	x.xxxxxx	REAL
V5ch1	volt 5 chan. 1	volts	x.xxxxxx	REAL
V6ch1	volt 6 chan. 1	volts	x.xxxxxx	REAL
V1ch2	volt 1 chan. 2	volts	x.xxxxxx	REAL
V2ch2	volt 2 chan. 2	volts	x.xxxxxx	REAL
V3ch2	volt 3 chan. 2	volts	x.xxxxxx	REAL
V4ch2	volt 4 chan. 2	volts	x.xxxxxx	REAL
V5ch2	volt 5 chan. 2	volts	x.xxxxxx	REAL
V6ch2	volt 6 chan. 2	volts	x.xxxxxx	REAL
V1ch3	volt 1 chan. 3	volts	x.xxxxxx	REAL
V2ch3	volt 2 chan. 3	volts	x.xxxxxx	REAL
V3ch3	volt 3 chan. 3	volts	x.xxxxxx	REAL
V4ch3	volt 4 chan. 3	volts	x.xxxxxx	REAL
V5ch3	volt 5 chan. 3	volts	x.xxxxxx	REAL
V6ch3	volt 6 chan. 3	volts	x.xxxxxx	REAL
V1ch4	volt 1 chan. 4	volts	x.xxxxxx	REAL
V2ch4	volt 2 chan. 4	volts	x.xxxxxx	REAL
V3ch4	volt 3 chan. 4	volts	x.xxxxxx	REAL
V4ch4	volt 4 chan. 4	volts	x.xxxxxx	REAL
V5ch4	volt 5 chan. 4	volts	x.xxxxxx	REAL
V6ch4	volt 6 chan. 4	volts	x.xxxxxx	REAL
V1ch5	volt 1 chan. 5	volts	x.xxxxxx	REAL
V2ch5	volt 2 chan. 5	volts	x.xxxxxx	REAL
V3ch5	volt 3 chan. 5	volts	x.xxxxxx	REAL
V4ch5	volt 4 chan. 5	volts	x.xxxxxx	REAL
V5ch5	volt 5 chan. 5	volts	x.xxxxxx	REAL
V6ch5	volt 6 chan. 5	volts	x.xxxxxx	REAL
V1ch6	volt 1 chan. 6	volts	x.xxxxxx	REAL
V2ch6	volt 2 chan. 6	volts	x.xxxxxx	REAL
V3ch6	volt 3 chan. 6	volts	x.xxxxxx	REAL

NAME	DESCRIPTION	UNITS	FORMAT	TYPE
V4ch6	volt 4 chan. 6	volts	x.xxxxxx	REAL
V5ch6	volt 5 chan. 6	volts	x.xxxxxx	REAL
V6ch6	volt 6 chan. 6	volts	x.xxxxxx	REAL
Popen	power open (average)	mW	xxx.xxx	REAL
Pclos	power closed (average)	mW	xxx.xxx	REAL
Pdiff	Pclos - Popen	mW	xxx.xxx	REAL
Taper	aperture temp.(active)	deg. C	xxx.xxx	REAL
Tshtr	shutter temp. (active)	deg. C	xxx.xxx	REAL
Ang	sun angle(average open)	degrees	x.xxx	REAL
Corr	correction due to temps	W/M^2	xxxx.xxx	REAL
SI	SOLAR CONSTANT	W/M^2	xxxx.xxx	REAL
soltime	DPU time	millisec.	xxxxxxxx.	REAL
Covcm	cover command	O,C	x	CHAR
Lshcm	left shutter command	O,C	x	CHAR
Rshcm	right shutter command	O,C	x	CHAR
Ssdcm	servo side command	R,L	x	CHAR
Sstcm	servo state command	0,1	x	CHAR
Refcm	reference command	0,1	x	CHAR
Balcm	balance command	0,1	x	CHAR
Covst	cover status	E,O,C,M	x	CHAR
Lshst	left shutter status	E,O,C,M	x	CHAR
Rshst	right shutter status	E,O,C,M	x	CHAR
Ssdst	servo side status	R,L	x	CHAR
Autost	auto state	0-15/no	xx	CHAR
Sstst	servo state status	0,1	x	CHAR
Refst	reference status	0,1	x	CHAR
Balst	balance status	0,1	x	CHAR
zflag	data flag	Dok,Din	xxx	CHAR
sflag	sun flag	Sok,Sno	xxx	CHAR
csflag	calibration flag	eC,nC	xx	CHAR
Date	PC date	string	xxxxxxxx	CHAR
Soltime	DPU time	string	xxxxxxxx	CHAR
Comtime	PC time	string	xxxxxxxx	CHAR

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Final Report

16. Abstract

The Solar Constant (SOLCON) Experiment, the objective of which is to determine the solar constant value and its variability, is scheduled for launch as part of the Space Shuttle/Atmospheric Laboratory for Application and Science (ATLAS) spacelab mission. The Ground Support Equipment (GSE) software was developed to monitor and analyze the SOLCON telemetry data during flight and to test the instrument on the ground. The paper presents the design and development of the GSE software. The SOLCON instrument was tested during Davos International Solar Intercomparison, 1989 and the SOLCON data collected during the tests is analyzed to study the behavior of the instrument.

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